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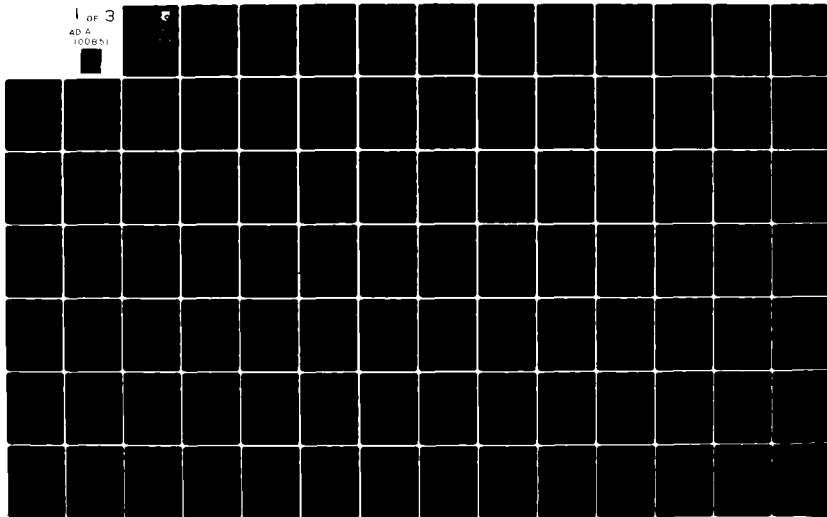
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KC-135 CREW SYSTEM CRITERIA



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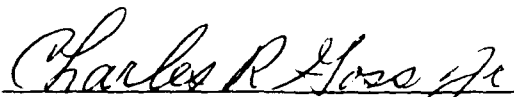


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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This document presents design criteria for the KC-135 Crew Systems to be developed under the KC-135 Avionics Modernization Program. It summarizes the objectives, requirements and constraints of the Strategic Air Command (SAC) (as embodied in the KC-135 Avionics Modernization Program) which have potential impact upon crew system requirements or which serve to put crew system activities in proper perspective.		

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20. ABSTRACT

A methodical detailing of requirements and criteria for the crew system is presented, as well as a tracing of the logic by which they are derived from the intended mission, from the overall Weapon system and from the sub-system capabilities and needs. Additional detailing and constraints have been derived from behavioral data and pilot factors considerations elicited in experimental programs utilizing dynamic mockups, simulation and flight test.

A testing procedure is described for determining degree of compliance with requirements and criteria.

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FOREWORD

The "Driver" for any Warfare System is mission needs. The intention in this document is to relate detail design to the Driver. It provides design information down to a detailed level and provides the means for tracing these details back to the mission needs. The intent is to establish the rationale that links each detail to its mission needs and to the system concept as defined by the Using Command.

Sections I and II present an overview of the mission and systems concept of the Using Command. They provide a framework against which detailed needs are to be developed. They establish the criteria for selecting and defining the system or subsystem capabilities necessary to achieve the mission and system concept.

Section III redescrines and expands upon the concept of Sections I and II. The restructuring is to organize the requirements in terms of functions needed and to expand the description to include requirements which are either implied or are derivations to support those initially specified. The content is aimed at providing an awareness sufficient to put the judgment of crew system details in proper context.

Section IV addresses the crew system issue as a system rather than as a collection of bits and pieces of equipment. It attempts to delineate the total characteristics of the system and to define those characteristics. This is done in terms of needs and constraints for the crew system design needs. These needs were originally established in the context of the mission and system concept of Section I and II. They are further defined in terms of technological capabilities, cost tradeoffs and established principles of the applicable technologies.

Section V attends to the methods of testing the suitability and effectiveness of any crew system which is proposed for compliance with the criteria herein.

Section VI describes a means for organizing and assimilating the test data and for deriving an assessment based upon those test results and the subjective judgement of consulted experts.

The structuring in a systems context does not mitigate the need to focus on specific topics in the actual design and development effort. Format and indexing of this document provide the opportunity to readily separate all data relevant to a specific designer's sections as control, information, etc. Extracting by topic (e.g., hydraulic, oxygen) from each section gives the complete story for a specialist.

As you read the book you will notice statements specifying requirements for systems that are already part of the aircraft and do not need to be specified as new requirements. They are included here because this document has a broad system orientation and the new crew system criteria need to be presented in the total system context. Considerably more detail could be provided, but is not since most of the present C-135 systems are adequate.

The crew system requirements and criteria detailed herein are firm only to the extent that requirements and constraints remain as defined and that the assumptions used are valid.

The development of these design criteria was conducted under a Memorandum of Understanding between the Aeronautical Systems Division (ASD/SD28, Airlift Systems Program Office) and the Flight Dynamics Laboratory (FDL), Wright-Patterson AFB Ohio.

This report was prepared in part by ORLOC located in Kettering, Ohio as a sub contractor to the University of Dayton under USAF Contract F33615-79C-3030 and in part by the Bunker Ramo Corporation, Electronics Division, Human Factors Group under USAF Contract Number F33615-78C-3614 located in Dayton, Ohio. Mr. Richard Moss (AFWAL/FIGR) is the Program Manager. The work was under Project/Task Number 23915200.

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GLOSSARY OF TERMS

NOTE: All terms within this glossary are not found within the report. They are included, however, because they form the common language used by the design community. Their importance is in having a common reference from which to communicate with others. AF Manual 11-1 is the standard reference for terms not included in this glossary.

AIRBORNE SIMULATOR TEST - A testing of the proposed design in a specialized test aircraft. A complete hardware representation of the proposed design is incorporated in an aircraft (in the cabin or as an appendage on the nose). Sophisticated computer and control devices permit tailoring the real or apparent dynamics of the test vehicle to those of the design vehicle performance in a flying environment. This is considerably more expensive and time consuming than all prior tests. It can yield data not otherwise available and produces the highest level of confidence in the results, except for OT&E.

AIRCRAFT SUBSYSTEMS - Lesser systems which are components of major aircraft systems. For example, subsystems of the hydraulic system might include landing gear, brakes, wing flaps, nosewheel steering and speed brakes.

NOTE: The terminology "system" and "subsystem" are often used synonymously.

AIRCRAFT SYSTEMS - Major components of the aircraft which operate from a common source of power, provide a common power source to similarly powered components, or perform a major function engulfing lesser functions or components, e.g., hydraulics, electric, flight control, pressurization and air conditioning, engine power, fuel.

ARCHITECTURE - Design and selection of all facets, establishing character, style, the collective relationships, the structure (e.g. federated vs control computers, multiplexing, language, executive control, redundancy, groupings and isolation).

ASSESSMENT - Appraisal -- to judge the character, the value.

AUSTERE AIRFIELDS - Those airfields without navigation aids and in most cases, short landing areas without paved landing surfaces and other facilities necessary for operation of typical medium/large size transport aircraft.

COCKPIT INTERFACE - The means provided for the flow of information to and from the pilot. These include the display of information available to the pilot as well as the type and characteristics of the cockpit controls.

COMPONENT SIZING AND PARAMETER DERIVATION - An analysis of the functional vehicle design to identify, organize and quantify the relevant parameters. (Example: Size and configuration of compartments and passageways and floor loading limits impose conditions upon workspace layout. Time to pressurize - can require isolation of flight deck.)

CONFIGURATION - The aircraft geometry as established by the actual position of movable portions and surfaces controllable by the selectors, and the state of operability of on-board systems.

CONTROLS - A distinction is made between the types of controls in the cockpit according to their function. Principal controls are the primary and secondary controls.

Primary - Those controls used by a pilot to continuously modify the movement of the aircraft.

Examples: Pitch, roll, yaw controls, throttle, DLC.

Secondary - Those controls used by a pilot to make discrete changes in the movement or balance of the aircraft, thereby modifying the need for actuation of the primary controls.

Examples: Pitch, roll, and yaw trimmers, aerodynamic braking devices.

Selectors - Those cockpit controls available to the crew for changing aircraft configuration.

Examples: Flaps, slats, wing sweep, DLC.

CONTROL/DISPLAY PARAMETER DERIVATION - An analysis of the mission, the mission equipment and the vehicle to identify, organize and quantify the specific parameters to be monitored and controlled. (Example: Analysis of the mission profile, considering all exigencies, is a procedure which will permit the designer to delineate altitude range, accuracy and rate of change of altitude for both barometric and absolute conditions. This is information which must be displayable for control purposes.)

CONUS AIRWAYS - The established Federal airway route structure in the United States is defined by a series of ground-based navigation aids broadcasting magnetic bearing information on the very high frequency band (VHF) from 108.0 to 117.9 MHz and distance information on the ultra high frequency (UHF) band from 962 to 1213 MHz. Area Navigation (RNAV) Routes and terminal procedures based on RNAV are in being and are extensively used in FAA future plans. An RNAV capability with a vertical navigation capability will be necessary. The equipment must receive the respective broadcast information and provide aircraft lateral and longitudinal position information to the aircrew. Range and vertical navigation information must also be available for the aircrew.

The Federal Aviation Administration (FAA) requires that all aircraft operating within Federally controlled airspace be readily identifiable to their ground, radar-based traffic control system. The aircraft must be equipped with an identification beacon capable of transmitting certain selected, coded signals receivable by FAA radar. The FAA also requires that aircraft operating within controlled airspace remain in voice contract with the ground-based airspace controlling agencies. All of these agencies transmit and receive voice on the VHF band from 118.0 to 135.9 MHz. Additionally, some of these agencies transmit and receive on the UHF band from 220.0 to 399.9 MHz. Coastal airspace controlling agencies also transmit and receive on the HF band from 2.0 MHz to 29.999 MHz.

CREW DUTIES - The tasks to be performed by a single crew member or the division of duties to perform the design scenario when the system is operated by more than one crew member. Tasks are assigned based upon operator skill specialities, space and geometry available for location of operational components, stress levels and time available versus time required to perform the task. (Example: Pilot's tasks include flight control, power control, communication, scanning for other air traffic, etc. Navigator's task include operation of long and short range navigation systems, operation and interpretation of the radar system, fuel planning, etc.)

CREW SIZING - The number of crew members is established considering: operator workload, degree of automation, limitations in system/vehicle size (i.e., space to operate), cost factors and desires of the customer. (Example: Tasks of flight control, communication, navigation, power control and mission performance require 2 pilots, 1 navigator and 1 flight engineer. Space limitations and customer desires restrict the number of crew members to a maximum of 3 people. The design is revised to reallocate duties among crew members AND the machine. Redesign of equipment or inclusion of additional automatic capability is probable.

CREW SYSTEMS - The interface between the aircrew and the aircraft systems including controls, displays and operational procedures/logic; that portion of aircraft systems/subsystems that are affected by the aircrew.

CRITERIA - A standard of judgment; an established principle for testing.

DESIGN SCENARIO - Portions of the total mission scenarios that are selected for use in designing the system and for bench mark testing. Segments of the total mission scenario have been eliminated because they were contained within other segments, determined to be noncritical, determined to be redundant or for other similar reasons. The design mission scenario may be described in the same variety of ways as the total mission scenario (i.e.,

summary narrative, narrative, ribbon-in-the-sky, altitude/timeline curves, design scenario timeline). Typically, it is described in all of these ways during the process.

DESIGN REVIEW - A formalized process where by designated representatives of various concerned organizations review and critique the design. This is conducted during the design process and may be repeated several times. The trial design is described to the Design Review Panel and they in turn may view it intimately in the mock-up. The members submit written remarks, critiques and requests which serve as guidance to the design team. It provides a useful check on concerns of standardization and static design features. However, it makes no attempt to deal with the dynamics involved with mission scenarios. Typically, the Design Review Panel includes a representative for each of such organizations as procurement, management, logistics, operations, I.G., requirements and engineering.

DYNAMIC REVIEW - A relatively new procedure which emulates the "Mock-up Review" but extends the effectiveness of the review process. It is used by the design team for the development process and for presentation to the Review Panel. The procedure includes a representation of the dynamics to be encountered by the crew during the mission. One or more crews "operate" the system in accordance with the design scenario. The three major changes from the Design Review are (1) mission oriented test subjects (2) test conducted against the design scenario and (3) tests conducted in an experimental manner. (Example: 10 crews, each consisting of a pilot, copilot, navigator and loadmaster, all currently qualified to perform the USAF tactical aerial resupply mission, are trained on the systems with which they were unfamiliar, provided with checklists for normal and emergency systems operation, briefed on the missions contained in the design scenario, and provided with all necessary forms and flight publications. The crews then "fly" the design (or series of designs) by simulating performance of all tasks as they are guided through the mission by the experimenter's script. Experimenters collect subjective data through questionnaires and debriefings.)

DYNAMIC TEST (SIMULATION) - A testing of the proposed design against the Design Scenario using simulation to represent aircraft dynamics and avionics. Simulation of the visual scene and cockpit motion may be included. This is an iteration of the Dynamic Test (Mock-Up) process with a considerable increase in the sophistication of the test and fidelity of replicating a real world condition. The increased sophistication and fidelity provides a significantly higher degree of confidence in the results. It is expensive and time consuming and therefore justifiable only after simpler screening devices e.g., Dynamic Test (Mock-Up) and Design Review have given adequate assurance of the validity of the design. The equipment should simulate, as closely as possible, an operational model of the proposed system design. The test is conducted similarly to the Dynamic Test (Mock-Up), using the same caliber of test subjects, and the

same design scenario. Both subjective and objective (performance) data can be collected with the more sophisticated equipment. (Example: Mission qualified aircrews test the system design by performing the design scenario in a flight simulator with all of the controls and displays installed, on which most of the critical systems simulate operation. Experimenters provide representation of communication stations - tower, ground control, other aircraft. Realism also requires ground school, flight training, preflight briefings and post flight debriefings.)

EASILY INTERPRETABLE - Values and/or information displayed can be determined with a high degree of accuracy without additional measuring devices/scales.

EVALUATION SCENARIO - Portions of the Design Scenario that are selected for use in testing/evaluating the system. Ingredients are chosen to represent most "worst case" uses/operations and to condense the Total Mission Scenario so that less time is required during the testing phase. The evaluation scenario may be described in the same variety of ways as the Total Mission Scenario, however, it is typically only described in the form of an evaluation scenario timeline. (Example: Long, relatively inactive inflight cruise segments may be eliminated, similar type maneuvers may be flown only once rather than repeatedly, and mission segments may be condensed or combined to address the issues only during the high aircrew workload portions.)

EXPERIMENTER'S SCRIPT - The words to speak during mission communications and the actions to take (staging) by the experimenters during the test/evaluation process so as to assure that all test subjects receive essentially the same information inputs. The script is placed along the same timeline as the evaluation scenario. (Example: At time 01:28 + 15, Boston Center transmits, "Blue one flight, climb to FL300. Change to New York Center on 133.95 and report to them passing FL280 and leveling at FL300.")

FAILURE STATE - A steady-state failure characterized by the various failed systems that affect the handling qualities. The dynamic effect of a failure is called a change of state and should be noted separately.

Examples: Any failure resulting in loss of selected function. Engine failure, augmentation system, failure in stability, autothrottle, primary flight control system (power boost, electric stick, servo control feel, etc.) or secondary flight control system (trim, aerodynamic brake, etc.).

FLIGHT or SORTIE - A complete sequence of flight phases of an aircraft within one of its roles. Full or complete mission.

Example: The composite of takeoff, climb, cruise, combat (or other special phase), descent, approach, landing.

FLIGHT PHASE - A designated portion or segment of a complete flight. A mission phase. A flight phase may be represented by one or more separate tasks.

Examples: (a) Common phases -- takeoff, climb, cruise, descent, approach, and landing.
(b) Special phases required by role -- formation, refueling, air-to-air or air-to-ground combat, weapon delivery, emergency conditions (i.e., 2- or 3-engine operation, emergency descent, etc.), VTOL transition, VTOL hover, STOL takeoff, and STOL approach.

FLIGHT SUBPHASE - That part of a flight phase having a single objective, and a single configuration or change in a configuration.

Examples: Air-to-air tracking, terminal area holding, glide slope capture, localizer capture, ILS tracking, wave off.

FORMAT - A symbol or group of symbols arranged in a specific manner to portray/display information.

FUNCTIONAL REQUIREMENTS - A description of the total needs of the Warfare System organized and expressed as a listing of all of the capabilities which the weapon system must have (or contain) in order to satisfy the needs of the requestor.

FUNCTIONAL SYSTEM DESCRIPTION - A description which identifies and describes, in conceptual terms, the subsystems proposed to satisfy the capability needs listed under Functional Requirements. Also described are the significant interrelationships among these conceptual subsystems. This is, in effect, the first overall description of how the weapon system is to be structured and how it is to function.

HANDLING QUALITIES - Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

INTUITIVELY OBVIOUS - Can be described or operated correctly without training or explanation.

MANEUVER - A planned and regulated movement of an aircraft for the purpose of aiding the completion of a given control task.

Examples: Bank, turn, dive, pullup, turn reversal, roll reversal, rolling pullup, steady sideslip, return from sideslip, control steps and pulses, maintenance of a steady condition.

MISSION - The objective, that is, the task together with its purpose, thereby clearly indicating the action to be taken and the reason therefore. The composite of pilot-vehicle functions that must be performed to fulfill operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

MISSION DESCRIPTION - A description of the job or jobs to be done. It addresses the intent or end objective and includes a fair amount of detail in terms of the employment and conditions of operation. The total effort stems from an adequate and complete mission description and therefore the quality of this effort determines the quality of the design product. Extensive coordination with the customer is essential. (Example: Vehicle is to support Ground Forces by transporting troops and supplies to the battle area. Transport a special forces team with full gear and equipment to an aerial drop zone behind enemy lines where enemy threats to the aircraft exist.)

MISSION NARRATIVE - A description of the planned use of the system told in story (essay) form. Description is presented in terms of the real sequence and describes roles, activities, relations and events. (Example: The aircraft will depart Boston as leader in a 3 ship formation, carrying a 23 man special forces team, 2 jeeps and a 1 ton truck. The flight will proceed at an altitude of 27,000 feet to Newfoundland and rendezvous with a KC-135 tanker. The story continues with route, destination, enroute weather, enroute mission tasks, threat, recovery procedures, etc.)

MISSION SCENARIO TIMELINE (TOTAL, DESIGN, EVALUATION) - A very detailed description of all uses/operations that the system must be designed to perform in its expected operational environment. It includes task performed by the aircraft and each of the crew members shown against the time (elapsed, GMT, local, etc.) at which the task occurs. This is one of the methods by which the appropriate mission scenario may be described. Example: At time 1:23 + 30, Pilot adjusts power, begins climb to FL300. Copilot reports to ATC "Requesting FL250", Loadmaster briefs passengers on oxygen mask requirements.

MISSION TASK DEFINITION - A description of the various tasks which make up a specific mission. (Example: Precise positioning in space with respect to a restricted drop zone. Maintain stabilized flight while dropping large cargo mass. Establish and maintain secure communication with ground troops. In-flight refueling during return leg.)

MOCK-UP REVIEW - A formal review of the design being presented in its intended final form. The Mock-up Board is to make the final decision on acceptance of the design for fabrication. Composition of the Board includes the same organizations as participated in the Design Review but generally at decision making levels. Conduct of the review is essentially the same as a Design Review.

MOCK-UP SHELL - A full scale replica of the system wherein all dimensions of the vehicle are accurately presented. It includes accurate location and dimensioning of structural members which relate to (or interfere with) the crew compartments and their equipments.

OPERATION - A military action, or the carrying out of a military mission, strategic, tactical, service, training, administration; the process of carrying on combat, including movement, supply, attack, defense and maneuvers needed to gain the objective of any battle or campaign.

PANEL LAYOUT - Arrangement and location of the components in workspace/panel space available. Consideration is given to grouping functional activities, operational control, etc. The controls and displays are arranged on the panels and consoles according to some pattern such as the systems that they pertain to, access to the crew member who will operate the system, ingress/egress considerations, vision requirements, etc. (Example: Attitude is aligned with pilot's center line and HSI is directly below the attitude on the center line for symmetry and correlation with control actions for control of line of flight.)

PERFORMANCE - The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot-vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

REQUIREMENT - Something essential to the aircraft/weapon system. The need or demand for personnel, equipment.

RIBBON-IN-THE-SKY - For purposes of briefings and discussions, an artist's concept sketch is often used to provide a pictorial representation of the total flight path for a mission. Sketch includes three dimensional data and notations of specific task objectives (e.g., orbits, refuel, LAPES).

SORTIE - An aircraft on a mission or in direct support of such a mission. (One take off and one full stop landing)

SPECIFICATION - A detailed, precise description of the weapon system, its hardware, software, geometry or other design parameter.

STATE - The mass distribution and failure situation that determine completely the behavior characteristics of the aircraft. A state without a failure is a normal state.

STATEMENT OF NEED (SON) - The requirement for a system as stated by an operational organization. Usually a general description of the desired system and its intended use. It may also contain some very detailed needs or constraints. (Example: Vehicle will be a large jet transport aircraft capable of rapidly moving a company of troops and their equipment to worldwide locations and landing at austere airfields. The system must include anti-skid braking.)

SYMBOL - A sign or code used to represent something else.

SYMBOLOLOGY - One or more symbols which make up a format to portray/define information.

SYSTEM VALIDATION - "Proof of the Pudding". The ultimate test is operation of the real and total system in the context of the real problem. It is for this purpose that prototype vehicles are built. Emphasis in the prototype programs has been upon vehicle and propulsion aspects. However, the increasing expense and risk of effectiveness related to avionics and crew performance are making total prototype validation more realistic.

TASK - The actual work assigned a crew member to be performed in completion of or as representative of a designated flight segment.

Control - That part of a task which requires continuing actuation of the principal controls and use of the selectors (see "CONTROLS") as required.

Examples: Movement between specified points, tracking part of weapon delivery, ILS or VOR tracking.

Auxiliary - That part of a task which involves the crew member in actions other than direct control of the aircraft.

Examples: Navigation, communication monitoring, and selection of systems.

TASK ASSIGNMENT (MAN-MACHINE ALLOCATION) - The very specific duties of the aircraft and each crew member during the design mission scenario. Each crew member's tasks are placed on the timeline based upon predetermined operational procedures, systems training, access to the controls and displays and coordination process with other operators. (Example: At time 1:28 + 30, Pilot moves throttles to set climb power, checks power indication on gauges, pulls back on elevator control to begin climb from FL250 to FL300, checks aircraft attitude and airspeed on flight instruments. Copilot presses microphone button, transmits report to Boston Center that aircraft is leaving FL250 and scans outside the aircraft for other traffic. Aircraft maintains lateral course through autopilot and navigation management systems.)

TEST PREPARATION - All of the actions taken by the experimenters and support personnel in preparation for the test. Generally, the more sophisticated the test, the greater amount of preparation required. (Example: Fabrication of test vehicle; design and fabrication of experimenter's station and equipment; preparation of the test plan to include experimental design type of data to be collected, specification, selection and obtainment of test subjects, and test agenda; training materials for the subjects including descriptions of the systems and weather, route, threat, mission, crew operating procedures; briefing materials including mission, route, threat, fuel, weather, etc.; test operating materials including experimenter's script and operational checklists; data collection including objective data parameters, methods and formats, and questionnaires, debriefings and observation forms for subjective data.

TIMELINE ANALYSIS - A derivation of time and motion studies wherein all the monitoring and control requirements for the entire mission scenario are examined against a time base. The time interval can be a fraction of a second for highly active flight phases or changed to several second or minute intervals where activity is relatively dormant. This is an aid in estimating workload, and allocating tasks among the crew or to the machine.

TOTAL MISSION SCENARIO(S) - All portions of all missions or sorties that the aircraft will accomplish. Typically many portions are repetitious, such as takeoff, climb and cruise segments accomplished under similar environmental conditions. All mission scenarios must be considered during the mission analysis phase of design in order to assure that all aircraft capabilities are defined. The total mission scenario(s) may be described in any of several ways including (1) summary narrative, (2) narrative, (3) ribbon-in-the-sky, (4) altitude/time profiles and (5) mission scenario timeline. Typically, only summary narrative and narrative are prepared during the process.

VALIDATION - To substantiate. To confirm. To give official sanction, confirmation or approval.

VEHICLE DESCRIPTION - A generic description of the vehicle which is needed, or proposed, to meet the SON. (Example: The aircraft will be a four engine turbojet, high wing, large footprint STOL transport capable of being aerial refueled as a receiver and transporting outsize cargo.)

VEHICLE FUNCTIONS DESCRIPTION - A description which is essentially internal to the vehicle. It is directed to the internal working of the vehicle and the functions which the vehicle must have in order to satisfy the generic description and the mission requirements. (Example: High altitude equipment, heating and cooling, pressurization to cope with the planned ranges of altitude and weather; auxiliary power and self start for remote

locations; lift augmentation and drag devices for short fields, self contained navigation for operation to remote areas worldwide.)

WORKLOAD - The integrated physical and mental effort required to perform a specified aircrew task.

Physical - The effort expended by the pilot in moving or imposing forces on the controls during a specified piloting task.

Mental - Mental workload is at present not amenable to quantitative analysis by other than pilot evaluation, or indirect methods using physical workload (input) and the task performance measurements. An example would be the improvement associated with flight-director type displays which reduce the mental computations normally required of the pilot.

WORKSPACE LAYOUT - The geometry of the entire crew station. The crew station is the mobile office where man, machine and job interface and where decisions are made. The validity of those decisions and the resultant success or failure of the mission are directly related to how well the crew station is designed to fulfill the requirements of the crew members. (Example of things to be considered during layout: seating, panels, consoles, reach, vision, visibility, ingress/egress, lighting, headroom, etc.)

LIST OF ABBREVIATIONS

A/A	Air-To-Air
ADD	Attitude Director Display
ADF	Automatic Direction Finding
ADI	Attitude Director Indicator
AFFDL	Air Force Flight Dynamics Laboratory
AFWAL	Air Force Wright Aeronautical Laboratories
AGL	Above Ground Level
AHRS	Attitude and Heading Reference System
AOA	Angle of Attack
A/R	Air Refueling
APU	Auxiliary Power Unit
ARA	Airborne Radar Approach
ARCP	Air Refueling Control Point
ARCT	Air Refueling Control Time
ARINC	Aeronautical Radio Incorporated
ARIP	Air Refueling Initial Point
ASD	Aeronautical Systems Division
ATC	Air Traffic Control
BDHI	Bearing-Distance-Heading Indicator
BITE	Built In Test Equipment
CADC	Central Air Data Computer
CAS	Calibrated Airspeed
CG	Center of Gravity
CDU	Control Display Unit
CRC/GCI	Combat Reporting Center/Ground Control Intercept
CRT	Cathode Ray Tube
DF	Direction Finder
DLC	Direct Lift Control
DME	Distance Measuring Equipment
DOD	Department of Defense
DR	Dead Reasoning
DSUS	Defense Satellite Communications System
EPEPS	Electronic Converter Electrical Power Supply
EGP	Exhaust Gas Temperature
EMP	Electro-Magnetic Pulse
EPR	Engine Pressure Ratio
EWO	Emergency War Order
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDL	Flight Dynamics Laboratory
FL	Foot-Lamberts
FL	Flight Level
FPA	Flight Path Angle
GA	Go-Around
GCI	Ground Controlled Intercept
GMT	Greenwich Mean Time (Zulu)
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GS	Ground Speed

HF/SSB	High Frequency/Single Side Band
HSD	Horizontal Situation Display
HSI	Horizontal Situation Indicator
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IFF/SIF	Identification Friend or Foe/Selective Identification Feature
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
I/O	Input/Output
JTIDS	Joint Tactical Information Distribution System
K	Knots (often precedes CAS, GS, IAS, TAS)
KHz	Kilohertz
LF	Low Frequency
MHz	Megahertz
MLS	Microwave Landing System
MRT	Military Rated Thrust
MSL	Mean Sea Level
NATO	North Atlantic Treaty Organization
NM	Nautical Miles
RAF	Royal Air Force
RMI	Radio Magnetic Indicator
ROC	Required Operational Capability
RPM	Revolutions Per Minute
SAC	Strategic Air Command
SEL/CAL	Selective Call
SON	Statement of Need
SSB	Single Side Band
SKE	Station Keeping Equipment
TACAN	Tactical Air Navigation System
TALAR	Tactical Approach and Landing Radar
TAS	True Airspeed
TRT	Take-off Rated Thrust
UHF	Ultrahigh Frequency
VHF	Very High Frequency
VMC	Visual Meteorological Condition
VOR	VHF Omnidirectional Range
WX	Weather

SECTION I

INTRODUCTION

This section provides the weapon system requirement as defined by the Using Command along with all formally stated goals, conditions and constraints.

This Design Criteria Notebook provides criteria for revision of the existing crew stations of the KC-135 aircraft under the "KC-135 Avionics Modernization Program" (Ref. 1).

In-as-much as mission performance is dependent upon the effectiveness of the crew and its ability to use the vehicle, it is incumbent upon the procuring and developing agencies to assure a crew system design which is compatible with crew behavior, capabilities, and limitations, vehicle performance, avionics equipment and the desired mission objectives. It is the objective of this document to provide, for use of the procuring and developing agencies, criteria which consider all of these factors in appropriate balance and in a total system context.

In developing the criteria, a methodical, iterative process is employed in conjunction with the Using Command, the System Project Office, the AFSC, and other agencies. It involves exhaustive descriptions of desired mission and vehicle performance, examination of crew/vehicle/mission interfaces, equipment assessment, trade-off studies and system performance assessment. The objective is the determination of the essential criteria to which a crew system must conform if it is to satisfy the goals (needs) of the Using Command for a specific weapon system.

The KC-135 Avionics Modernization Program is responsive to objectives set forth in SAC directives and Required Operational Capability (ROC) documents (Ref. 2). Specific goals are improvement of navigation system performance, modification of the crew complement through elimination of the navigator and installation of modern navigation systems. These have been strictly observed in the drafting of criteria.

Detail program objectives are as follows:

1. Reduce crew size by eliminating the navigator position. Functions now performed by the navigator will be handled by
 - (a) Incorporating the functions in a revised avionic suite or:
 - (b) Assigning them to another crew member, or
 - (c) Eliminating them.
2. The revised crew system will have greater capability than the present system.

3. All communications/navigation and subsystems functions must be capable of being monitored or controlled from both pilot and copilot stations.
4. Automatic features of the system should be under pilot management. The system should at all times inform the pilot of what it is attempting to do (e.g., maintain altitude, follow a course) and provide the pilot with means of assessing its progress in achieving that performance.
5. The system should advise the pilot of its own status and capability, including remaining capability in a partially failed mode.
6. Capability must be provided for the pilot to make easy and natural control inputs. Waypoint coordinates, for instance, should be insertable in any of a number of ways, including; latitude/longitude, bearing/distance, or grid coordinates.
7. Changes in procedures and in the forms to be used will be considered if system effectiveness can be enhanced.
8. Improved cost-effectiveness is desired. Providing equipment on the tanker, rather than on the receiver is an acceptable means to achieve improvement.

Based upon an examination of the objectives set forth in the documents the following additional conditions were inferred:

1. Integration of navigation, radar, and autopilot systems is required for automating some flight operations.
2. Crew systems modifications should be compatible with other modifications projected for the KC-135 fleet, and should take advantage of the increased operational capabilities provided by the new systems. Projected modifications which affect crew systems (Ref. 3) are:

ARN-116 TACAN	In progress - FY81
APN-59E(V) Radar	In progress - FY81
Inertial navigation system	In progress - FY82
Common strategic doppler	In progress - FY82
ECEPS solid state converter	FY83 - 88
HF/SSB radio	FY82 - 83
VHF radio ARC-186	FY84 - 85
UHF/VHF secure voice	FY82 - 86
Global Positioning System (GPS)	FY82 - 84
AHRS and Autopilot Gyros	FY83 - 86
Winglets	FY83 - 88
Re-engine Program	FY83 - 90
Standard Fuel Savings Advisory System	FY83 - 83
Advanced Air Refuel Boom	FY84 - 87

SECTION II

WEAPON SYSTEM

This section provides the genesis of the weapon system requirement. The mission, as the driver and motivator, has been developed by the Using Command.

Operating conditions and weather complicate the problem and pose additional requirements upon the system. The actual vehicle and subsystems do not have unlimited capability (a technology limit and a physical limit) and therefore, in the context of mission desires, must be regarded as a constraint.

The proposed mission applications are described and examined for their requirements impact upon the vehicle and crew. To facilitate the examination and to provide a bench mark for subsequent assessment of candidate designs, a composite is established of all critical mission tasks in a complete and realistic scenario of employment of the Weapon System. This is identified as the Design Scenario.

A. MISSIONS. This is a multi-mission aircraft capable of: (1) transporting aircraft fuel and providing inflight refueling; (2) airlift of cargo and personnel.

1. FUEL TRANSPORT/AIR REFUELING. The system is to transport fuel for use in designated USAF, USN, USMC, and NATO aircraft. It is to rendezvous with other aircraft and perform air refueling.

a. RENDEZVOUS. To accomplish an air refueling the system must rendezvous with the receiver aircraft by navigating to a predetermined location, then utilize various means compatible with that of the receiver to arrive at a position within visual range of the receiver. The means presently utilized to accommodate any type of rendezvous are: (1) search radar with the capability of receiving/displaying range and bearing/beacon signals and skin paint; (2) TACAN capable of transmitting/interrogating TACAN range signals to and from the receiver; (3) UHF direction finder capable of receiving a signal in the UHF frequency band from the receiver and displaying a bearing to that aircraft; (4) others, including ATC, CRC/GCI, HF radio, IFF, Timing and visual. After visual contact has been made, aircraft lighting systems provide illumination for night refueling operations and for signaling the receiver into position during radio silence operations. For normal daytime refueling, voice communications are used to signal the receiver into position. (Ref. 4).

b. FUEL TRANSFER. The system is to be capable of refueling suitably equipped receivers through a standard USAF boom system or drogue system. Some KC-135 aircraft have highspeed booms but these are not addressed in this program.

2. AIRLAND DELIVERY. The aircraft provides accommodations and environment appropriate to the transport of personnel and cargo. Ground equipment may be required for loading and unloading.

a. CARGO. A cargo capability of up to 68,000 pounds is required. Loading and unloading must be compatible with standard cargo handling equipment.

b. PASSENGER. A capability is required for accommodating 80 passengers. This capacity is to be reduced to 41 personnel when equipped with an arctic kit.

B. SPECIAL NEEDS AND CONSTRAINTS. The mission is global in scope. It must be accomplished day or night in a hostile environment and under adverse weather conditions. The vehicle performing the mission must be operationally compatible with commercial/civil navigation and traffic control systems and able to function from military sites.

1. ENVIRONMENTAL. Normal mission operations are to be conducted day or night in any weather (clear of thunderstorms and moderate turbulence) of greater than one mile visibility for the refueling function and greater than 200 foot ceiling and 1/2 mile visibility for landing. Weather conditions of rain, fog, snow or light icing should not impair mission capability. Threat conditions have been projected by SAC, for normal and Emergency War Order (EWO) missions. They are not defined in this document and do not impact the crew system criteria. (Ref. 4)

2. OPERATIONAL. The system must be capable of limited operation into austere fields without external electronic guidance in weather of 400/1 (visibility of 400 feet vertically and 1 mile horizontally) or better. It must be capable of interfacing with civil air traffic control systems and of operating with state-of-the-art electronic and visual guidance equipment at civilian and military air fields. The system must provide the capability to operate within both foreign and domestic airway structures and terminal areas as well as the capability to navigate precisely over direct routes -- land and sea. It must be capable of operating globally under wartime conditions without dependence upon ground-based navigation aids.

The system must operate globally within Federal Air Regulation (FAR) (Ref. 5) and International Congress of Airline Operators (ICAO) tolerances. (Capabilities meeting these tolerances will also meet the enroute navigation mission requirements.) The aircraft must interface with other classes of military/civilian aircraft within the various air traffic control systems.

The aircraft systems must have capability to display the relative location of: severe weather areas so that they may be avoided, other aircraft in the formation, receiver aircraft for purposes of refueling rendezvous' and ground surface returns for airborne radar approaches and airborne alignment/update of the inertial navigation system.

3. COMMUNICATION. The system must have the capability to maintain two-way communications with other aircraft and controlling agencies. To accomplish the mission, communications must be maintained with the mission control element, receiver aircraft, other aircraft in the formation, air traffic control worldwide, command post, search and rescue and between crew members within the tanker.

4. GROUND SUPPORT. This aircraft is to be capable of interface and operation with currently available aircraft servicing equipment, material handling equipment, and standard navigation and traffic control equipment. No special ground handling equipment is to be required.

C. VEHICLE. The KC-135A, manufactured by the Boeing Airplane Company, is a four engine, swept wing, long range, high altitude, high speed aircraft with a primary mission of global air refueling of designated aircraft (Ref. 4). The KC-135A may also be used in a secondary role as a cargo carrier or troop transport.

1. PERFORMANCE. The following performance/payload descriptions are to provide limits for design criteria as they affect the aircrew station and aircrew workload.

a. SPEED. The aircraft possesses a speed range compatible with the requirements of all current fixed wing receivers. The effective refueling speed range to be considered is from 252 KCAS (C-5A) to the boom speed limitations of 330 knots calibrated airspeed or Mach 0.85, whichever is lower.

b. ALTITUDE. The aircraft is capable of providing air refueling to current receivers at low, intermediate and high altitudes. Cruise altitude capability is compatible with receivers on "buddy" cruise missions. The range of operating altitudes extends from ground level to approximately 50,000 feet (absolute ceiling).

c. RANGE. The aircraft is capable of global ranges, meeting requirements dictated by operational considerations and receiver capabilities/missions. It is capable of using all fuel carried onboard to meet severe range requirements (12,000 + n.m range).

d. LANDING. Routine, safe operations onto hard surfaced runways of 10,000 feet or longer is required. The aircraft must be capable of receiving electronic information from sources on an airport with state-of-the-art equipment, to include VHF and UHF voice communications, ADF, TACAN, VOR and ILS navigation signals. Additionally, as airport systems are upgraded other sources such as MLS and TALAR may be operationally required and must be included as a condition to be met in the design.

e. PAYLOAD. The aircraft, in addition to its primary mission of air refueling, possesses a limited cargo and passenger carrying capability.

(1) FUEL. The aircraft is capable of transporting and off-loading inflight all except 7,800 pounds of onboard fuel (180,000 pounds total or with upper deck tank 203,000 pounds) in order to meet current mission requirements dictated by anticipated mixes of tankers, receivers, and missions.

(2) CARGO. Fuselage weight and space capabilities not dedicated to the air refueling mission are available and equipped to transport cargo. Up to 68,000 pounds of cargo may be carried on cargo carrying missions.

(3) PASSENGERS. The carrying of passengers is possible because the cargo compartment is pressurized, air-conditioned, and has provisions for seating 80 persons on permanently installed, collapsible, side-facing seats or 60 removable, aft-facing, airline seats. This capacity is reduced to 41 persons for aircraft equipped with an arctic kit.

2. ENGINE POWER. Loss of an engine during critical phases of flight, particularly during terminal area operations, will not prevent either pilot from executing a safe recovery or go-around. The engines must have a "quick start" capability which allows them all to be started simultaneously should the mission dictate.

a. THRUST (ENGINE). A variety of functions are necessary and used in the control of thrust from either pilot seat. The KC-135 is equipped with four Pratt and Whitney J57-59W or -43WB flat rated thrust, dual axial flow turbojet engines which also provide operation of hydraulic and electrical power generation, air conditioning, and pressurization.

b. ENGINE STARTING SYSTEM. The engines are equipped with cartridge pneumatic starters, allowing either cartridge starts for quick reaction or pneumatic starts from ground power carts or from an operating engine.

c. ENGINE OIL SYSTEM. Each engine is provided with an integral pressure-type oil system with automatic temperature control.

d. ENGINE FUEL CONTROL SYSTEM. Throttle control causes the four individual hydromechanical fuel control units to meter proper fuel quantity for start, stop, and a variety of thrust settings.

e. ENGINE FIRE DETECTOR AND CONTROL SYSTEM. This system provides the engine overheat warning for each engine and provides engine systems isolation as well as the capability to extinguish the fire.

f. WATER INJECTION SYSTEM. A water injection system provides thrust augmentation by allowing water to be sprayed into the air inlet and diffuser section of each engine.

g. ENGINE IGNITION SYSTEM. The engine ignition system provides ignition for both ground and flight starts.

3. AUXILIARY POWER.

a. ELECTRICAL. Primary electrical requirements are for 115/200 volt, 400 cycle power. To a lesser degree there is a need for 28 volts and 32 volts as well as 24 volts DC. The system should be relatively independent, imposing little need for crew work, however, individual systems control and monitoring is required. Circuit breaker protection is necessary to isolate equipment faults. A redundant and isolated electrical power supply system is required for flight essential functions. The AiResearch or Solar APU presently provide this redundant capability.

b. CABIN HEAT. An independent source of cabin heat is required for arctic operation. The AiResearch or Solar APU presently provide this capability.

c. HYDRAULIC. There are two independent high pressure systems which supply pressure to the various hydraulically operated components.

4. AVIONICS. The avionics package must provide for routine, day, night, safe, global IFR/IMC operation including: long range over-water deployment without use of external navigation aids; approach down to Category II ILS minimums; with external navigation aids, non-precision minimums without external nav aids; weather avoidance; air refueling rendezvous both active and passive, station keeping; ground locations; receiver craft locations and identification; short and long range voice communications systems to satisfy all mission requirements internal and external to the aircraft; autopilot and augmented flight control system with integrated navigation course guidance.

5. ENVIRONMENT. The pressurization, air conditioning, oxygen and lighting must be suitable for transporting passengers and operational equipment during employment and deployment missions in a wide range of environmental conditions, where temperatures range from -40° to 130°F. An oxygen system with sweep on oxygen masks is required adjacent to each aircrew seat in the cockpit, for each position in the boom pod and for two positions in the cabin. Additionally, provisions are necessary to provide emergency descent oxygen for the maximum number of personnel on board. The aircraft must be sound-proofed to the degree that operating noise and vibration are not detrimental to the crew's performances. The aircraft must have internal and external lighting suitable for all mission operations in all ambient light conditions.

6. SAFETY. A wide range of safety features must be incorporated, including: rapid ground and air egress, crash landing protection, detecting and warning of systems malfunctions, automatic switching to alternate systems, simplified critical action crew response and unrestricted crew visibility during all maneuvers.

D. MISSION SCENARIOS. Requirements for the overall weapon system and integral individual components which comprise it, have been derived by examining the operational employment of the system and validated through extensive review by the SAC.

When a number of employment concepts and operational uses are involved, the weapon system's requirements for each must be considered. The design of the weapons system must then take into account the total requirements. Very detailed mission scenarios were developed to describe the current and anticipated employment of the KC-135. They were developed against a time base (Ref. 5) to consider the dynamics evoked by mission performance. These were then validated by all knowledgeable agencies involved in the KC-135 Avionics Modernization Program including, Hq SAC, ASD, and AFWAL.

A composite mission scenario which included all significant mission tasks and which was realistic in terms of geographic and environmental aspects was defined as a bench mark for design, evaluation and assessment of crew systems. This Design Mission, portrayed in Figure 1 involves moving a five ship tanker force from Loring AFB to support an A-7 unit deployment from McGuire AFB to RAF Wittering. Subsequently, (Figure 3) the KC-135 embarks upon an EWO task in a two ship cell of KC-135's wherein the lead KC-135 experiences an emergency abort for fire and the subject aircraft encounters a refueling track weather diversion and minimum fuel. Subsequent failures cause degraded mode operation. In "leg 3" (Figure 4) refueling of fighters is complicated by different type emergencies including combat injuries.

This scenario exercises all subsystems and crew in the severest performance demands and exhibits various aspects of degraded mode performance. A detailed description is presented in Appendix A.

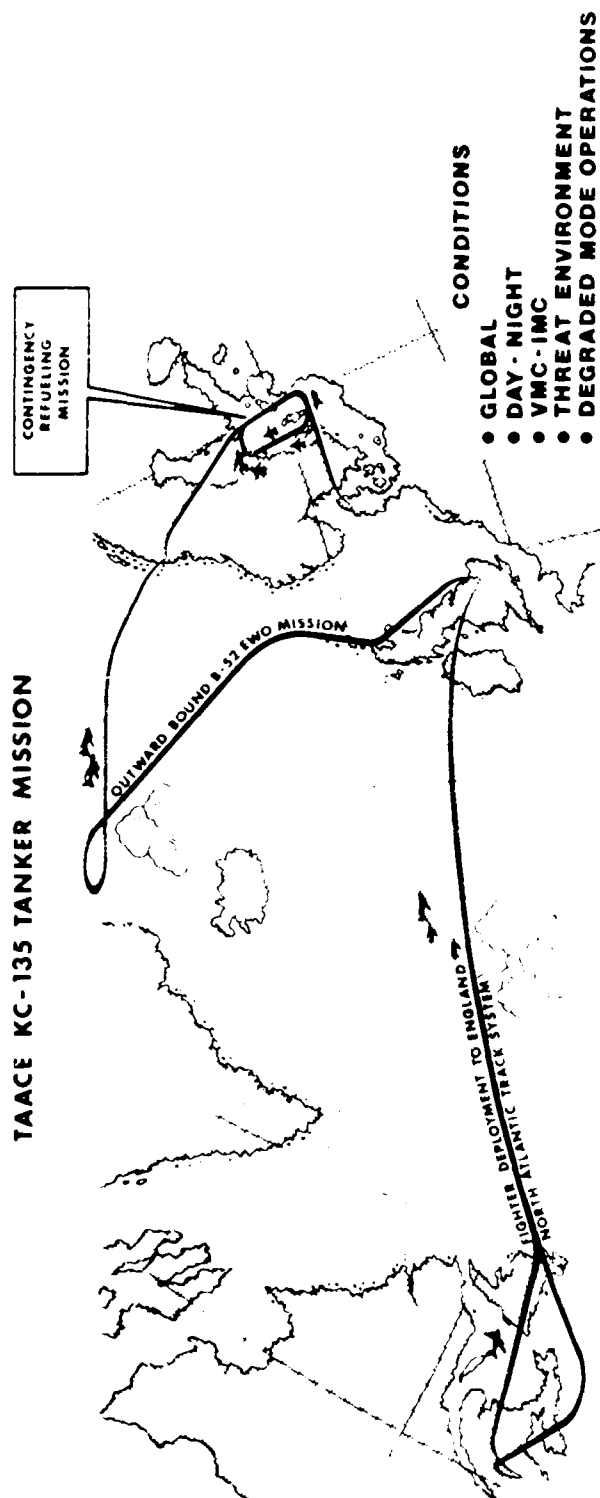


Figure 1. Ribbon-in-the-Sky

FIGHTER DEPLOYMENT SUPPORT - LORING TANKER FORCE

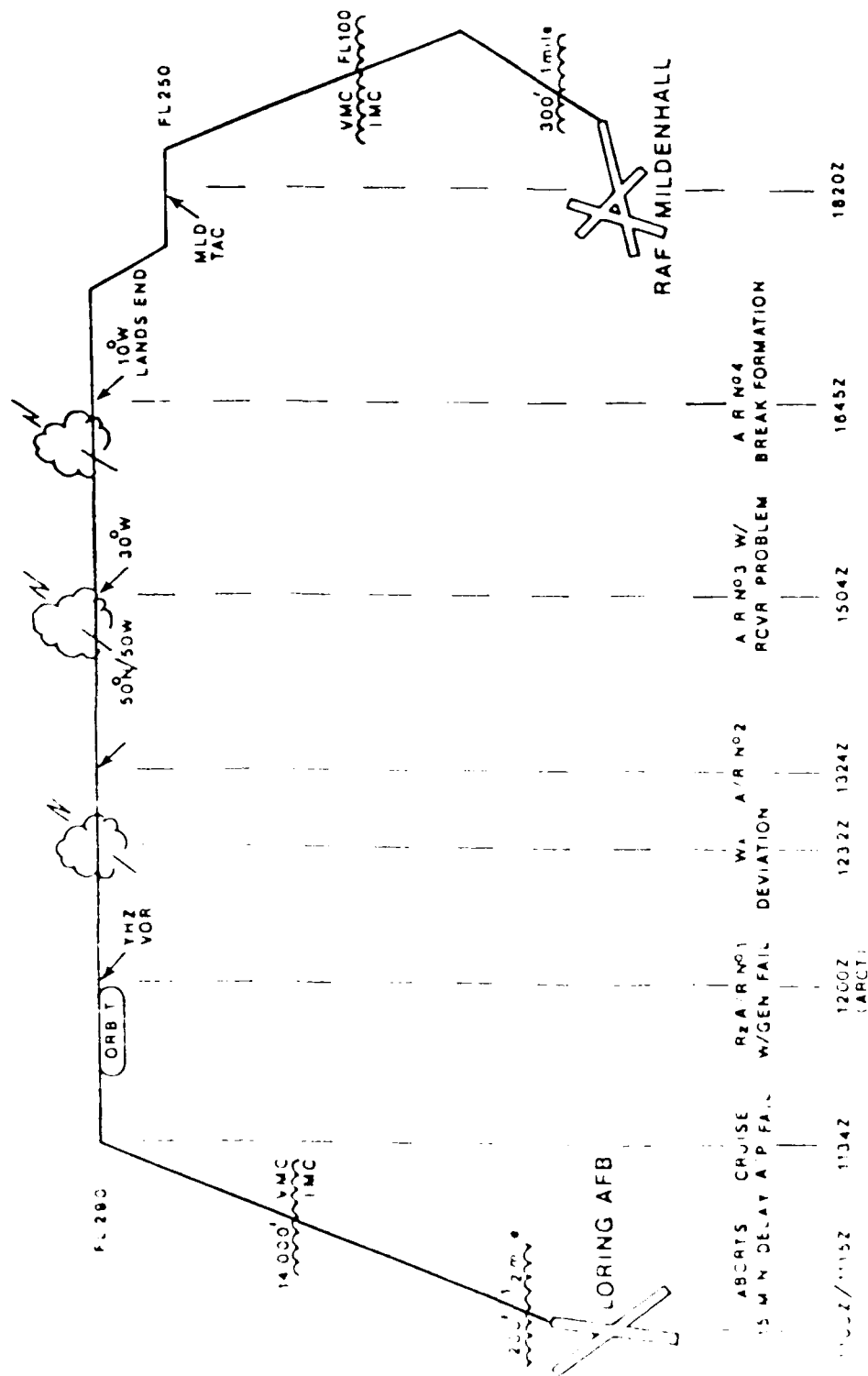


Figure 2. Time/Altitude Profile -- Sortie #1

MILDENHALL EWO MISSION

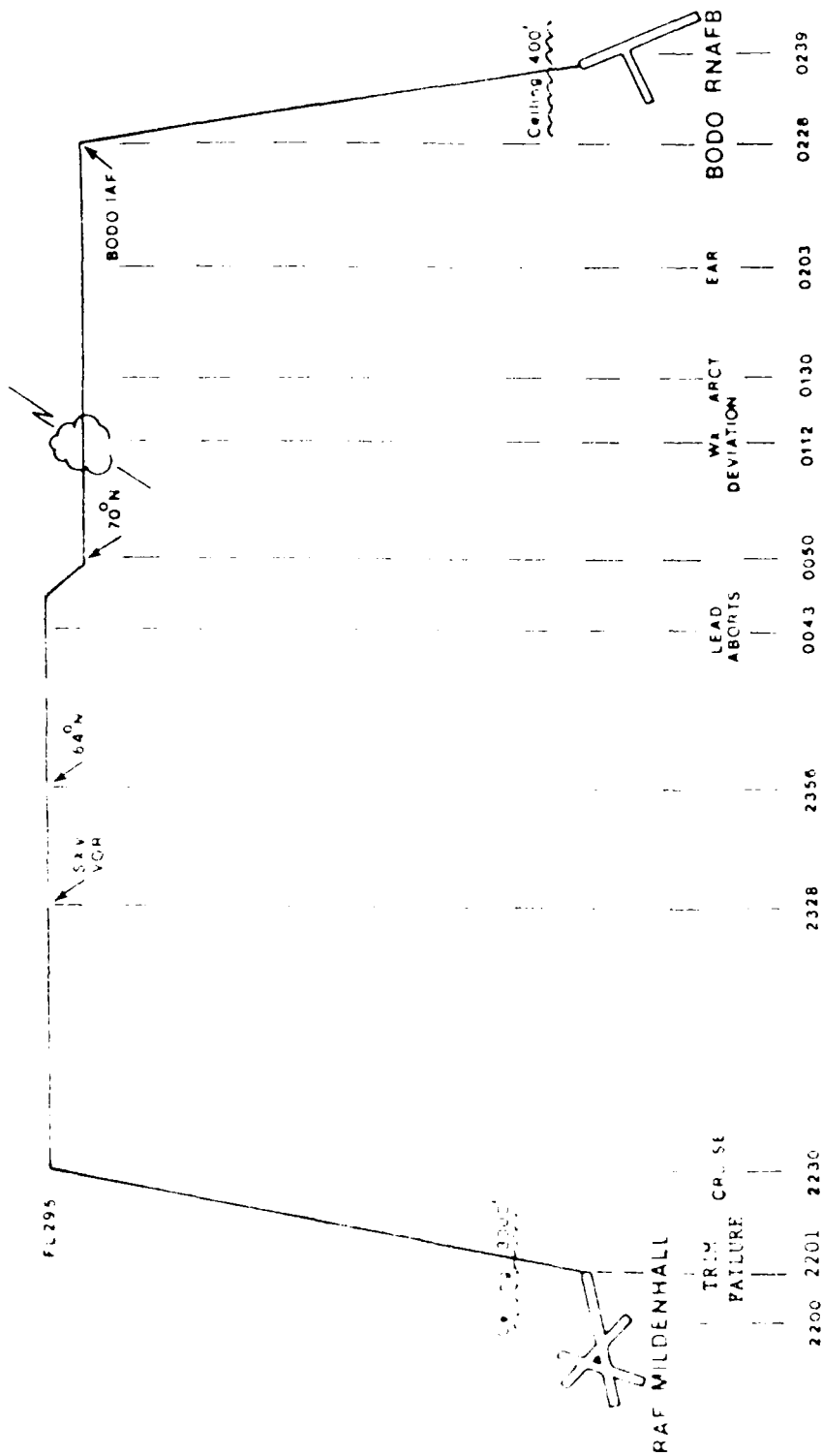


Figure 2. Time/Altitude Profile -- Sortie #2

BODO CONTINGENCY MISSION

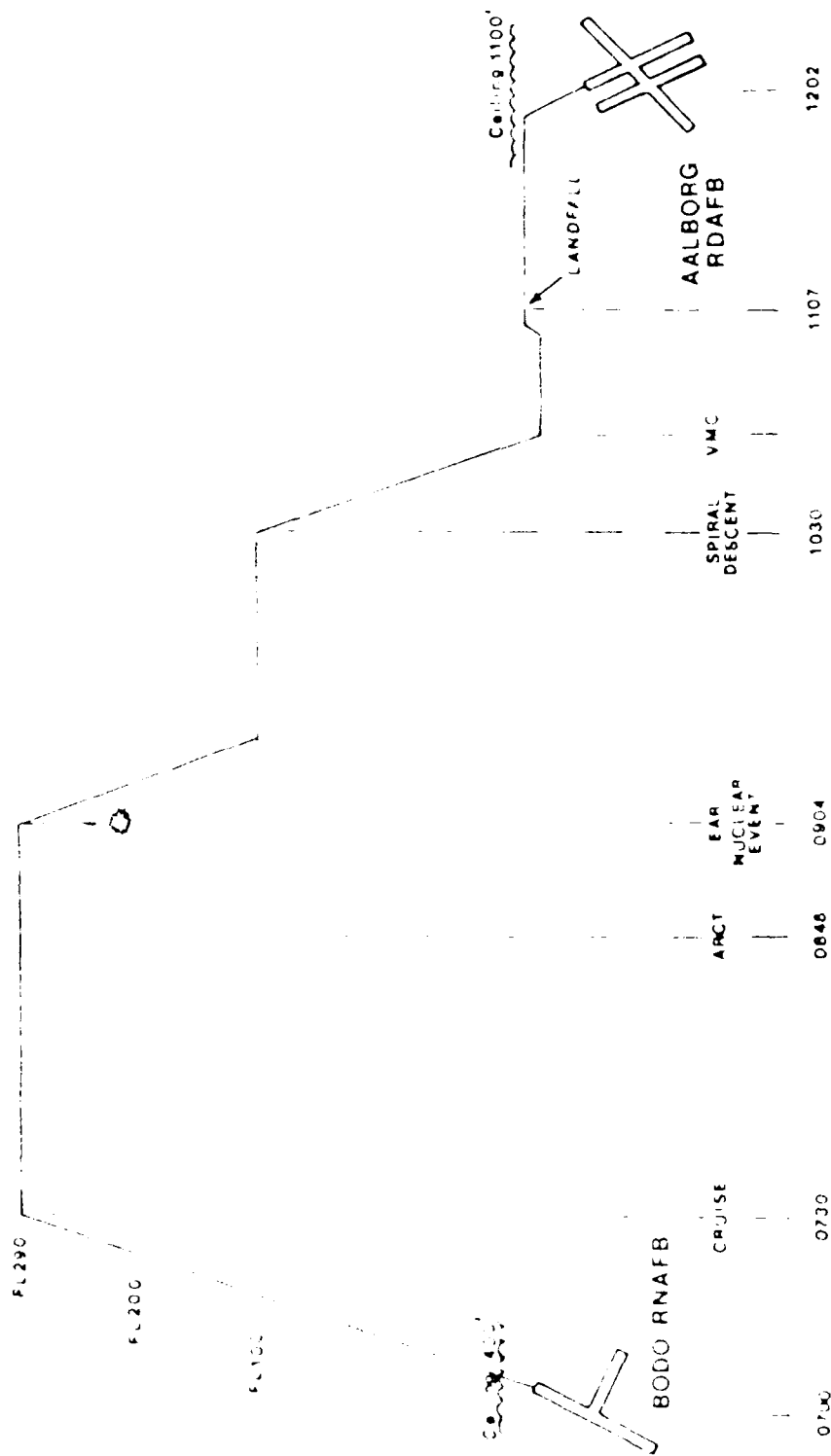


Figure 4. Time/Altitude profile -- Sortie #3

SECTION III

IMPLIED REQUIREMENTS (FIRST DERIVATION)

Sections I and II described the job to be performed and the conditions which the Command imposed. The conditions can be economic, technological or operational constraints, but they do set down the conditions to be met for satisfactory solution of the mission problem.

In order to perform the mission under the conditions given, a multitude of functions are needed. These are "implied requirements". Examples: (1) In order to operate at night the crew must be able to see, thus there is an implied requirement for lights (a simple example), or (2) in order to operate globally, there are many implied requirements such as assistance for the crew, long range communication, space-time-position information (a more complex example).

This section addresses the task of translating the mission requirements into the functional requirements to be provided by systems on board the vehicle. A system of typifying Section III could be "in order to travel from point A to point B under position control you must have a continuous knowledge of your position in space with respect to ground reference, i.e., a Navigation System). Furthermore, you must have a radio system that will allow you to talk to the control center over a distance of 2000 miles. These systems must be compatible with equipment on other USAF aircraft and with the conventions for identifying location such as latitude/longitude. The derivation of a functional need and identification of suitable systems can create additional (or second order) requirements. The inclusion of a system (as in example 2 above) can impose needs for systems of support operations of the included systems.

A CAVEAT -- where clear definitive needs were not established, assumptions or judgments were made. Whenever this was done it is so noted.

A. MISSION OPERATIONS.

1. ENVIRONMENTAL.

a. GENERAL. The aircraft is to be capable of routine operation under adverse conditions and of emergency operation under weather conditions approaching the aerodynamic limits of the airframe, i.e., crosswind, wind shear, etc. In order to operate in virtually all weather conditions globally there must be systems which provide for the proper functioning of the vehicle under such extreme conditions as freezing rain. Since the planned vehicle has limits on the degree of weather which it

was voluntarily, and without coercion, and that it was not a military territory. While the United States Government, the Navy and the Air Force were not directly involved, the United States is the most responsible power in the world for the creation of this situation. It is the responsibility of the United States Government to ensure that no more violations of international law will be required to permit close flying with the aircraft of the United States and other countries under conditions of international law. The United States approaches to landing, flight, and departure with the United States approach aids a self-contained system. Global visibility and mission control are required for the need to have a significant self-contained system for the United States under ICAO.

[illegible]

1. SEALING - Sealing of all client plan mailboxes and the following is used to seal the mailboxes: areas associated with transportation, food, clothing, or other life support. All client areas are sealed and required to be changed of 340 miles with detailed records and labels for 6" and 10 mile ranges.

4. Lighting. "Aircraft flying at night and for air refueling operations at night must meet the following requirements. In addition, lighting for collision avoidance and for landing is required. Internal cockpit and cabin lighting is required for the crew.

4. INSTRUMENT LANDING SYSTEM (ILS): The primary navigation system provided at civilian and military airfields for the approach to landing, made of light in the instrument landing system (ILS). This system consists of lateral guidance signals (localizer) and vertical guidance signals (glideslope) which are transmitted on two radio frequency signals. The glideslope signal is transmitted on a frequency of 111.3 MHz. The aircraft ILS units should have standard features for operation to provide localizer and glideslope information to the pilot and to the autopilot system. It should be able to operate in ILS approach mode only. The ILS unit should also tune the VOR information to provide "full navigation" control.

1. Richardson, John H. and Smith, (MRS). This system, which is still under development (Ref. 6) (Ref. 7) (Ref. 8), or a similar type system will provide an improved capability for IMC precision approach operations into high density terminal control areas when that type of system becomes operational. It is anticipated that it will become operational during the life of this aircraft and therefore provision should be made for it.

g. MARKER BEACON. An outer and inner marker are required for making ILS approaches at most airfields. The airway marker is used when flying on airways in Europe and North America to provide navigational location or fix. This receiver should interrogate and display 75 KHz airway marker, outer marker and inner marker beacon signals on a three light display. Additionally, it should provide an aural coded signal to the communications system which the pilots can selectively monitor.

2. OPERATIONAL.

a. GENERAL. The broad global capability to be established without having a dedicated navigator crew position poses significant technical and economic challenges. To perform as required, the aircrew must be able to position the aircraft globally (within FAA, ICAO, and mission tolerances) with respect to established routes, waypoints, terminal areas, and other aids for aircraft. Aircraft must be able to operate globally under wartime conditions without dependence upon external (groundbased or satellite) navigation aids, which at this point in technology, indicates an inertial system. Communication with applicable controlling agencies and mission aircraft is necessary. The aircraft must operate within both foreign and domestic airway structures and terminal areas as well as navigate precisely over direct routes -- land and sea. Consequently equipment must be provided which is capable of interfacing/interacting with the varieties to be encountered through the world. The system must have the versatility needed to interface with civil and military systems and must be automated to the degree that it does not overburden the crew. It must require little in-flight manipulation but provide ready access to information about flight plan waypoints, present position, and other positions of interest. The system must provide information for on and off a way navigation to FAA/ICAO tolerances, air refueling rendezvous with and without airborne radar, nonprecision instrument approaches in tactical and conventional environments with and without external navigation aids, and precision instrument approaches in conventional environment to Category II ILS minima.

Controls and equipment rack space and wiring provisions should be planned for future modernization to include such systems as the Microwave Landing System (MLS), Global Positioning System (GPS) and the Joint Tactical Information Distribution System (JTIDS) related navigation functions.

b. NAVIGATION. A long range navigation system capable of providing lateral and longitudinal position relative to the desired course and to some point on the earth's surface must be available for aircrew use on long, direct overland/overwater flights. Candidate systems include inertial, Omega and global positioning system (GPS).

equipment with which the aircraft must interface operates on the low, very high and ultra high frequency bands. Navigation and instrument approach aids broadcast omni-directional information on the VHF band from 108.0 to 117.9 MHz (VOR) and runway final approach lateral guidance on odd decimal frequencies on the VHF band from 108.1 to 111.9 MHz (ILS localizer). Glide slope information is transmitted on the UHF band from 329.3 to 355.0 MHz within which frequencies are paired with specific VHF localizer frequencies. Additionally, omni-directional and distance information is available on the UHF band from 962 to 1213 MHz (TACAN and DME). Aircraft equipment must be capable of receiving the approach aids and displaying lateral, longitudinal, and vertical guidance information to the aircrew. Location marker beacons transmit on 75 MHz and low frequency radio beacons transmit on 190 to 1750 KHz.

(1) INERTIAL. Long range navigation systems are necessary for traversing oceans and some large land masses. An inertial navigation system will provide the self-contained capability for both short and long range operations. It should have a minimum accuracy of 1-2 nautical miles per hour while functioning without update through other sensors. It should accept information and be updatable from other installed navigation sensors and ground mapping radar. To meet the wartime requirement it must be capable of being air-aligned and updated to provide accuracies similar to those achieved with ground alignment.

(2) OMEGA. While inertial is primary for long range navigation alternate techniques are advisable for reliability crosscheck and update. The Omega system provides worldwide coverage through a series of ground based navigation aid stations. This long range navigation system should have the capability to interrogate and use both Omega navigation stations and the Very Low Frequency naval communications network. This capability greatly increases the number of available stations and provides better area coverage, flexibility and accuracy. It should be capable of providing long range navigation information unilaterally or updating the inertial system to increase its accuracy worldwide.

(3) GLOBAL POSITIONING SYSTEM (GPS). The Global Positioning System, presently under development, is expected to provide worldwide navigation capability through the use of a network of space satellites with an accuracy of 10-20 meters. When operational this system, while it will not meet self-contained (wartime) criteria, may well provide the capability presently afforded by TACAN, LF/ADF, VHF and Omega. It is anticipated that this vehicle will be operating within the time frame of an operational GPS. Provision must be made for this capability.

(4) TACAN. A standard reference for bearing and distance to airfields, ground based navigation aids, and other reference positions is provided by TACAN. A TACAN system capability is necessary for operation both off-airways and within the

civilian airway system. The TACAN should have standard features and include fast lock-on capability for bearing and Distance Measuring Equipment (DME) for both air-to-ground and air-to-air operations. The air-to-ground mode must be compatible with radio aids to navigation, and the air-to-air mode must be compatible with the equipment of the USAF receiver aircraft. It must be capable of providing relative position information with respect to the navigation aids to the inertial navigation system for updating to improve accuracy. A DME extender to selectively provide reception up to 400 nautical miles is highly desirable.

(5) VOR. Federal airways are made up of a series of VOR stations which operate on the VHF band using even frequencies 108.0 to 112.0 and all frequencies 112.0 to 117.95 MHz (selectable to .05MHz). In order to fly on those airways, VHF navigation (VOR) capability is needed. The VHF navigation units should have standard features for operation to provide relative position information with respect to VOR navigation aids to the pilots and to the inertial navigation system for updating. The frequency tuning control must also tune ILS localizer (VHF) and ILS glide slope (UHF) frequencies, which are paired. Additionally, it is highly desirable to have the capability to receive VHF transmissions throughout the VHF voice frequency range for VHF communication redundancy.

(6) UHF/DF. The UHF direction finder should provide bearing information to any selected UHF transmitter within the UHF voice communications frequency range. It must be compatible with ground stations for navigation and other aircraft for relative positioning/rendezvous.

(7) LF/ADF. In order to utilize navigation information from navigational aids while operating in foreign countries and in order to receive standard ILS compass locator signals throughout the United States, the aircraft must have the capability to receive and display a bearing to low frequency transmitters. The low frequency automatic direction finder should have standard features to provide bearing information to low frequency transmitters operating throughout the 190 to 1750 MHz range. The control must be digitally tuneable.

(8) INTEGRATION AND FILTERING. The navigation system should be designed to provide the pilots with the most accurate information available from all onboard systems. Sensor information should be processed within the computer to automatically provide that information, however, the pilot must have the capability to obtain information from individual sensors when desired.

c. COMMUNICATIONS. The communication systems must provide the capability to communicate with all agencies within the command and control system and the operational environment as described in the design mission scenario. This necessitates an

intraplane system; a system for long range voice compatible with command posts and overseas airway stations; a short range voice system compatible with air traffic controllers, airborne command posts, receiver aircraft and intraformation aircraft; and other special features.

(1) INTRAPLANE. The aircraft must have the capability for two-way communication between crew members located in the cockpit, cabin and boom pod, without broadcasting outside the aircraft except during engine starting operations. It is highly desirable that this intraplane capability be extended to include non-broadcast communication with receiver aircraft while they are in physical contact with the tanker. The public address system must be capable of providing audible information to passengers during operation at maximum cabin noise levels.

(2) LONG RANGE. The long range communications must be an interference free voice system. The system must operate on the high frequency (HF) band between 2.000 and 29.99 MHz to be compatible with overseas air route traffic controllers. The aircraft must have worldwide capability to receive voice messages transmitted by mission control. The transmissions may be direct or relayed via aircraft or satellite communications systems. During peacetime operations, two-way communication with mission control is required. The system must be adaptive to secure voice and jam resistant techniques.

(3) SHORT RANGE. The short range communication capability must be responsive to DOD, FAA, ICAO and mission environments. The aircraft must have the capability for two-way communications with air traffic controllers throughout the world. Airfield ground control, tower, approach control, departure control and enroute control have UHF (225.0-399.0 MHz) and/or VHF (118.0-135.9 MHz) frequency capability. Identification beacons (IFF/SIF) for use with air traffic control agencies and military radar controllers must be installed. The aircraft must have two-way communications capability with other aircraft within the cell formation and all receivers including USAF, USN, USMC and NATO aircraft within a range of 200NM. Aircraft typically have receive and transmit capability on the UHF and/or VHF frequency bands. Secure voice capability must be provided on the UHF frequency band.

Console and equipment rack space and wiring provisions should be planned for future modernization to include such systems as the Defense Satellite Communications System (DSCS) and the Joint Tactical Information Distribution System (JTIDS).

d. MISSION EQUIPMENT. The wide variety of mission tasks described in the mission scenario dictate some specific crew stations configurations and special equipment.

(1) AIR REFUELING. An air refueling system which provides for aerial rendezvous, and in-flight boom/droque refueling operations must include a radar rendezvous beacon system compatible with the USAF receiver. The capability to display the relative position of the tanker to the receiver and the position of the aircraft relative to the flight plan course on the same display is extremely desirable, e.g., overlay a flight plan map with rendezvous beacon signal. Workload and degree of attention dictates a crew position and operator for this function.

(2) STATION KEEPING. Multi-aircraft deployment to air refueling areas or aircraft dispersal locations require guidance and separation data for all weather, day/night, and in-trail formation flights. This is presently accomplished by displaying a radar beacon return or an aircraft skin-paint return on the radar display. The capability to display the position of the aircraft relative to the flight plan course on the same display is extremely desirable, e.g., overlay a flight plan map display with the radar beacon signal.

(3) THREAT. The type of threat that may possibly be encountered includes sabotage, electronic interference, surface-to-air missile, fighter interceptors, hijackers and electronic eavesdropping. The risk of some threats may be reduced through protective operational procedures, (e.g., sabotage, hijack and fighter interceptors), however, the aircraft should have the capability to reduce the risk of others (Ref. 9). A self defensive capability would not be justifiable considering the limits of speed and maneuverability of this vehicle and the penalties in weight, cost, complexity and reliability to be anticipated in a self defense system for this vehicle. (Ref. 10) For defense against enemy air action, reliance must be placed upon: route planning to minimize threat; adequate surveillance; secure, reliable command and control; navigation; and expanded fuel reserves for diversion purposes. The navigation system should have the capability to operate independently and not be dependent upon navigation aids which could be destroyed or jammed electronically. The navigation system must be designed so that it is not susceptible to passive listening threats; specifically the capability to extract information from signals generated by onboard computers and transmitted to displays (CRTs). This could pose a problem in exposing classified information such as destinations, air refueling points, flight plans, etc. The aircraft should have the capability to detect and counter heat seeking missiles. The operation of the equipment must be basically automatic, since its operation would normally be required during periods when the pilots' workload is already at a peak.

B. VEHICLE.

1. CONTROL. Control of the vehicle in flight is afforded by the conventional control surfaces (aileron, elevator and rudder) and augmented by a spoiler system. Hydraulic actuation provides

the necessary force for moving the surfaces. Considering problems of crew workload and reduced crew size an automatic capability is necessary. However reliability concerns dictate the need for fail safe and a basic manual capability. Engine control demands are minimal, requiring basically a throttle control device. However, such advances as coupling to the automatic system for energy/fuel management and for landing should be considered.

a. DRAG/LIFT.

FLAP SYSTEM. A hydraulic actuated wing flap system is installed to alter lift/drag for takeoff and landing.

SPOILER AND SPEED BRAKE SYSTEM. Lateral control of the aircraft is augmented with four hydraulically operated spoilers. These spoilers also act as speed brakes when used symmetrically.

b. STEERING (NOSEWHEEL). A hydraulically actuated nosewheel steering system is installed for ground maneuvering.

c. BRAKES. The aircraft has segmented rotor brakes, which operate from two interconnected hydraulic systems. They are activated by pilot or copilot toe pressure being applied to the brake control.

2. POWER.

a. ENGINE PERFORMANCE MONITORING SYSTEM. Indications of engine power and temperature, as well as engine oil temperature and fuel flow are displayed continuously to provide the crew with engine performance information required to make decisions regarding engine operation.

CAVEAT - Recognition that the aircraft performance is power limited has resulted in a potential class V modification to re-engine the aircraft under PMD revision R-Q 792(7)/11142F, 1 February 1979 (Ref. 3). Criteria for the new engines and the associated systems are not addressed. The crew systems (e.g., throttles, performance monitoring, and fire detection/control) associated with the engines must, however, perform the same functions as the present systems and be easily useable/interpretable by the crew.

b. FUEL. The airplane fuel system consists of integral wing tanks and a combination bladder and integral center section (body) tanks with the necessary manifolds, valves, pumps, and pressure and quantity indicators. Fuel supply and pressure to the engines is provided automatically through throttle control during normal operation.

The airplane can transfer fuel in flight to receiver airplanes from two body tanks. All fuel from all tanks, totalling 180,220 lbs. without or 202,801 lbs. with the upper deck tank installed, can be used by the aircraft. All except 7800 lbs can be transferred to receivers.

NOTE: The upper deck tank is not normally installed because the amount of thrust from the engines is insufficient to operate the aircraft with more than a 180,000 pound payload including fuel.

3. LIGHTING. Global operation under all weather conditions will require exterior and interior lighting for all conditions from bright sunlight reflected off snow to a dark moonless night over water. Operation in a "see and avoid" training environment as well as in a "minimum detection" combat support environment imposes a need for considerable flexibility in the exterior lighting.

a. EXTERIOR. Standard navigation lights, rotating beacon, landing and taxi lights, top and bottom fuselage strobe lights, ice detection lights, aerial refueling, inspection, and servicing lights for wings, engine nacelles, wheel wells, external power receptacles, fuel and oxygen service panels, external air conditioning receptacles and outside flood lights of exterior area for night on-load and off-load operations.

b. INTERIOR. Basically, standard interior lights are required. Lights are required for normal and emergency exits operative from an emergency electrical bus with the battery switch off and without an external power source. Instruments, panels, controls, placards must be easily visible and readable through the operational conditions.

C. LIFE SUPPORT.

1. ENVIRONMENT.

a. PRESSURIZATION. The pressurization system is capable of maintaining any selected cabin altitude between minus 1000 feet and 10,000 feet utilizing a maximum pressure differential of 8.6 psi between the cabin pressure and the ambient air pressure. The system may be operated automatically or manually and contains necessary controls, displays and warning devices. The aircraft automatically depressurizes on the ground and may be depressurized when airborne.

b. OXYGEN. Cockpit/cabin pressurization reduces the requirement for oxygen to that required for emergency use. Five regulators are installed in the cockpit, two in the cabin and two in the boom pod. Additionally, a portable oxygen bottle is located at each of these positions. Standard or quick-don oxygen masks must be available for each crew member.

c. AIR CONDITIONING. The air conditioning system provides cooling, heating, ventilation, humidification and contamination control for the cockpit and cabin. Each of these features are available on the ground as well as airborne.

2. SEATING. There are presently five seats installed on the flight deck which will continue to be adequate in event of a change in crew complement. The location/mobility of the seats must be such that vision, reach and egress requirements are met. The cabin area contains 80 collapsible seats and has provisions for up to 60 airline type passenger seats. The boom pod contains 3 couches or pallets.

3. ENTRY/EXIT. Normal and emergency ground and inflight exits consist of the main crew entrance, the cargo door, 3 emergency exit hatches and 2 cockpit windows.

4. SANITATION.

RELIEF FACILITIES. An enclosed latrine facility with toilet, urinal, towel dispenser, mirror, wet-napkin dispenser and lavatory with water supply is located between the cockpit and the cabin.

5. FOOD/BEVERAGE.

FOOD AND BEVERAGE FACILITIES. A galley unit with electric oven, 2 hot cups, one two gallon hot beverage container and 4 additional two gallon beverage containers is located in the forward portion of the cabin.

6. REST. Crew duty days may be extended beyond 16 hours when additional crew members and crew rest facilities are on board. Eight fold-down bunks are attached to the sides of the cabin and provide a place for sleeping.

D. CREW.

The accomplishment of the mission is the responsibility of the crew. The crew must be considered as an element of the system since their performance and capacity can significantly affect total system performance. Considering the capabilities of the crew and of the various equipments with which they do (or should) interface is a system design problem. (Consideration of the collective functioning of many interfacing elements and adjusting elements so as to influence the collective performance is system design.) Consideration of the crew and their interface with the elements of the system in the environment of the mission is the Crew System problem. In any system design, performance characteristics of an element must be known and considered. In the case of the crew, behavior and training are significant in establishing performance characteristics. (For this design assume that standard training and selection procedures are employed.)

While there are explicit and unique conditions which should be imposed as requirements on each subsystem from the Crew System design process (Ref. 11), there are overall requirements to which the Crew System must be responsive.

These are derived from the general Weapon System Requirements just as has been done for the more conventional "subsystems". These are "implied requirements" and include such things as survive, perform reliably, deliver accurately, improvise or compensate. Considering the mission requirements and the role of the crew system, there are classes of implied requirements. They fall within two categories: mission and workspace.

1. MISSION. The crew must continually monitor the status against the plan of the system including its own health and continually assess probability of success, be prepared for and responsive to perturbations (change of target, loss of light, unexpected enemy action, failure of equipment, etc.). Direct manual control must be blended with automation to maximize mission success and survival while retaining flexibility to deal with changes and failures. Executive responsibility must be established over the total system in an organized fashion. In this design, this responsibility is divided into the major areas of NAVIGATION, FLIGHT CONTROL, COMMUNICATION, and SYSTEMS STATUS.

a. NAVIGATION. In order for the crew to efficiently and effectively use the navigation information provided by the individual sensors, a navigation management system is necessary which incorporates computers, fast access bulk storage memory, an information filtering system and a control/display unit to interface the pilot with the navigation system. Generally, the navigation management system must provide precise navigation information worldwide, with and without external navigation aids. Additionally, it must provide the capability for airway navigation, nonprecision approaches and precision approaches.

An acceptable way of providing the aforementioned capability is a system consisting of an inertial navigation system (INS) which can be updated by all installed navigation sensors. (VHF NAV, TACAN, LF/ADF, GPS, OMEGA). The system should have the capability to automatically or manually tune the sensors to appropriate Nav aid station frequencies as the flight progresses. Unreasonable or erroneous information should be automatically filtered out and only the most accurate information used for updating. Navigation information should be available directly from any individual sensor, when the pilot desires.

b. FLIGHT CONTROL. The inflight refueling flying task is particularly sensitive to flight control. A high degree of precision and reliability is essential. A "Force Wheel" mode, which provides a basic automatic capability subject to direct incremental adjustments by the pilot, is highly desirable.

c. COMMUNICATION. Communication requirements are complex. Features include capabilities to talk inside aircraft only, broadcast with or without other crew members listening,

monitor diverse broadcasts simultaneously, and simultaneously carry out multiple conversations on different frequencies. The communication system must permit selection of the many modes, equipments and frequencies and allow flexibility in participation.

The following communications equipment is required to complete the mission: 2 UHF, HF, VHF, AM, Intercom, Air Secrecy Voice, Public Address, and IFF/SIF Transponder. Console and equipment rack space and wiring provisions should be set aside for future modernization to include such systems as the Defense Satellite Communications System (DSCS) and the Joint Tactical Information Distribution System (JTIDS).

a. SYSTEMS STATUS. The crew, in its executive role, must be assured of proper, effective operation of all aspects of the warfare system and alerted to any deviation from normal. This can be provided by monitoring and alerting devices, built-in testing capabilities, automatic switching to backup systems coupled with an alerting indication for the crew.

(1) BUILT-IN TEST EQUIPMENT (BITE). When technically feasible, all flight instrument control/display units and sensors should contain BITE for easy identification of malfunctions.

(2) CAUTION AND WARNING SYSTEM. Aircraft systems malfunctions and/or out-of-tolerance conditions should cause an alerting/warning signal to call the pilots' attention to that condition, so that prompt and proper corrective action can be taken. As a reminder of system status, the alerting signal should continue until the malfunction has been corrected. The caution and warning system should include master caution annunciators, a consolidated caution and warning light panel, and other dedicated visual, auditory and tactile warnings as required including an engine fire detector system as described in Section III.

(3) BACKUP. There must be backup instrument operation from independent sensors and triply redundant flight control with indication of failures.

2. WORKSPACE. Hardware requires provision for space, weight, power, cooling, and maintenance. The equivalent, for the crew, must also be considered, in terms of the crew needs and in terms of the system needs. These include Life Support, Vision, (external and internal), and Geometry. Both hardware and crew require consideration of environmental variation and the response of the eye to changes in ambient illumination (lighting, night vision).

a. LIFE SUPPORT. Crew life support functions, which affect crew workspace and physical environment include heat, restraining systems, environmental controls, relief facilities, rest facilities, nourishment, etc.

b. VISION.

(1) EXTERNAL VISION. External vision is required on the ground for taxi, takeoff and landing. During flight external vision is necessary for avoiding midair collision, formation flying, mission effectiveness and general orientation. Windows, compatible with this needs, must be provided to give the appropriate visibility forward, over the nose, over the side and upward. External vision must be enhanced by exterior lighting at night for landing, taxi and inspection of surfaces and engines.

(2) INTERNAL VISION. Placards, instruments, controls, maps, charts, and briefing instructions must all be readable under all lighting conditions expected. Control of impacting high level light and supplementary lighting for low level ambient conditions is required. Control must provide for variations in environment and mission requirements (e.g., protect night vision, flash blindness). Displays must be positioned in accordance with workload and priorities of action. Particular attention is required to insure that switches and knobs are visible in dim light.

c. GEOMETRY. Flight deck crew members must be positioned so that each is visible by all others. Exit/Entry provisions must take into account the likelihood of crew movement/interchange in flight and the avoidance of inadvertent actuation of switches, knobs, and controls.

2.2.1.1.1.1

CREW SYSTEM

The crew is the effector of the mission and the weapon system is the means (the device) which is used by them in effecting the mission. This orientation is a key U.S. Air Force philosophy in advancing warfare system capability.

The crew is the nucleus which welds vehicle, avionics, armament, power plant, etc. into an effective warfare system. The weapons system should support and enhance the ability of the crew to: (1) achieve the mission objective, (2) survive, and (3) cope with emergencies. The crew and the means by which they interface with the weapon system is the crew system. In this concept, the cockpit and other crew stations are prominent hardware aspects but are not the totality of the system. The crew members are elements and, just as awareness of technology is important to hardware solution, so is awareness of human behavior and training important to solutions involving the crew.

The crew must provide the judgmental aspects of the mission (continue, direct, abort). Effective judgments require adequate information on such things as significance of the mission (planning), probability of success (a variable, dependent not only on the form of battle but also upon reliability of equipment), probability of survival (a variable, also dependent upon equipment), and, certainly, training of the crew. The crew must be aware of the mission, the factors affecting performance (weather, threats, force structure, equipment status, battle dynamics), aware of status progress in accomplishment of the mission plan, aware of changes in the dynamics of tactics or strategy, and must control the vehicle. The control of the vehicle is a function of the crew which is sometimes relieved by automation.

This section addresses the device/functions necessary to interface the crew with the vehicle and its subsystems and with the mission problem. Considering this interface as a system, the material is organized as a description of the crew system requirements -- PHYSICAL CHARACTERISTICS (Geometry) -- INPUT (Information Requirement) -- OUTPUT (Control Requirement).

A. GEOMETRY. The flight deck or cockpit is the mobile office where man, machine and job interface and where decisions are made. The validity of those decisions and the resultant success or failure of the mission are directly related to how well the flight deck is designed to fulfill the requirements of the pilot. The pilots' requirements vary greatly with the type, length and urgency of the mission, crew size and complement, and outside

operating environment (geographic location, temperature, time of day, threat, external aids, weather, etc.). For these reasons, human factors considerations play an extremely important role in the cockpit design process.

The flight deck design criteria gives primary consideration toward placing the crew members in an environment where they can efficiently, effectively, safely and comfortably perform their duties. The design criteria contained in this document were predicated upon a minimum crew complement of three, consisting of a flight deck crew complement of two pilots, along with a boom operator whose primary functions are in the boom pod. Other crew members, while they may occupy a position on the flight deck, will not be checklist respondents or part of the minimum crew. The crew systems requirements are for systems, avionics and control/display units necessary for two pilots and one boom operator to accomplish the mission described in Section II.

The crew stations must be constructed and equipped so that the aircrews get the proper amount of information at the right time so as to permit them to make necessary decisions and perform the operational mission; the necessary information is presented adequately (i.e., easily interpreted, readily available); the accessibility of the information and controls are proportionate to the frequency and criticality of use; and the crew station environment is physically and psychologically aiding rather than reducing the crews' efficiency.

1. FLIGHT DECK. The forward portion of the cockpit (Ref. 12), located in the top front part of the aircraft, is large enough to accommodate two pilots seated side-by-side. Its design must allow all flight maneuvers to be performed by the pilot in either seat; however, wherever any compromise is required, it is more favorable to control the aircraft from the left seat. All critical items must be located within reach of both pilots, while less critical items may be located within reach of only one pilot. (See Figures 6 and 7 for description of reach zones.) The cockpit also accommodates a third seat located so so that the occupant has an unrestricted view of the front instrument panels, overhead and center consoles and outside the aircraft through the entire width of the windshields. The location of this seat must be adjustable so that the occupant can move it to a position where he can easily reach controls and displays on the present navigator's station (now designated as the forward boom operator's station). The flight deck should contain an additional reclining seat for an observer or additional crew member.

Figure 5 presents the general layout for the pilot/copilot portion of the Flight Deck.

2. VISIBILITY. This aircraft will be operating in close proximity to other tankers, receivers, and a multitude of other aircraft particularly in airport terminal areas. Therefore,

cockpit visibility required to "see and avoid" other aircraft is very critical (Ref. 13). Boom station visibility is also very critical. Each receiver must be visually vectored into the in-trail refueling position by the boom operator. Receivers approach the tanker as single ships or in formation. While refueling a formation of aircraft, one ship is refueling while the others remain in the vicinity. Facing aft from his position in the boom pod, the boom operator must have unrestricted lateral visibility 90° either side of the tail, 60° above and 90° below the longitudinal axis of the aircraft.

3. ENTRY/EXIT (Normal and Emergency). Normal entries/exits provide access to the flight deck without interference from the cargo/troop load or activities in the cargo compartment. Space and arrangement of seats and consoles provide easy access between the rear portion of the flight deck and crew seats for crew members wearing back-type or chest-type parachutes. Then utilize various means compatible with that of the receiver to arrive at a position within visual range of the receiver. Ground and ditching emergency exits include the pilot's and copilot's sliding windows, inward opening hatches above each wing, and the aft emergency exit hatch on the right side of the cabin. Additional ground exits include the crew entry chute at the left rear of the cockpit and the main cargo door. Inflight emergency escape may be accomplished by exiting through the crew entry chute or the aft emergency exit hatch.

4. SEATING. The cockpit crew seats (Ref. 14) are adjustable in the longitudinal and vertical axes and reclinable. They have firm but resilient seat and back cushions. Lumber support is desirable. The back cushion may be removed to accommodate wearing a back-type parachute. The arm rests are comfortably padded and may be stowed for easier access/egress. The height of the arm rests should be easily adjustable so that the elbows and forearms can rest at a comfortable elevation. Each should contain an ash tray, which can be extended from the end of the arm rest. Grip bars/hand grips for the pilots to grasp when they are maneuvering themselves in or out of the seat must be present. Additionally, foot rests are installed to provide a place where pilots can elevate their feet to reduce fatigue without damaging the instrument panel or other COUs.

5. ARRANGEMENTS/LAYOUT. Specific location of displays and controls (Ref. 15) (Ref. 16) for the complexities of this crew station are quite significant. Time of response, misinterpretation, overlooking or missing are directly related to the care exercised in designing the layout. Factors to be considered include frequency of use, relationship to other tasks, accessibility under differing degrees of constraint, emergency conditions, identification, readability, interpretability, and physical factors (size, weight, structural interference).

General guidance and constraints are indicated by describing panel and console area which can be reached with restraint harnesses locked and unlocked and by describing visual areas normally in the most sensitive area of view and those in areas of lesser criticality.

a. REACH AND VISION. Reach envelopes are depicted in Figures 6 and 7. All flight, drag and power controls are located within Reach Zone 1. Additionally, space is available for the placement of critical controls and displays within Reach Zone 1 and all CDU items within Reach Zone 3. Following are definitions of Reach Zones as used in this notebook (Ref. 17). They accommodate the 5th to the 95th percentile pilot.

Zone 1: Restraint Harness Locked-Functional Reach. This zone includes the area that can be functionally reached with the seat in the full up position by the fully restrained crew member without stretch of arm or shoulder muscles.

Zone 2: Restraint Harness Locked-Maximum Functional Reach. This zone includes the area that can be functionally reached with the seat in the full up position by the fully restrained crew member with the maximum stretch of the shoulder and arm muscles.

Zone 3: Restraint Harness Unlocked-Maximum Functional Reach. This zone includes the area that can be functionally reached with the seat in the full up position by the crew member with the shoulder restraint fully extended and the arms stretched full length.

Vision: Unobstructed vision through windshield and windows located on crew member's side of the aircraft with restraint harness locked and emergency oxygen in use.

b. CONSOLES. The cockpit must have overhead, center, pilot's side and copilot's side consoles of adequate size to position all required controls and displays. Present consoles provide adequate space with the exception of the pilot's center console which must be enlarged. The boom operator's aft station must have a panel of adequate size to position all required controls and displays within easy reach of the boom operator and with easy operability by the boom operator in a safety harness using emergency oxygen.

The pilot's overhead console (Figure 8) is approximately 4 standard ARINC control panels wide at the forward end and approximately 6 panels wide at the rear. Eyebrow windows on either side provide better turn visibility. The aft end is constructed and mounted so as to preclude pilots from bumping their heads as they enter their seats. The console should primarily contain aircraft system controls and displays.

LEGEND FOR FIGURE 5

- | | |
|--|--|
| 1. Angle of attack | 18. Water injection panel |
| 2. Mach/airspeed indicator | 19. Landing gear lever |
| 3. Flight director annunciators | 20. Flap position indicators |
| 4. Acceleration indicator | 21. Vertical velocity indicator |
| 5. Master caution light | 22. Clock |
| 6. Altimeter | 23. Outside air temperature |
| 7. Marker beacons | 24. INS/AHRS select switch |
| 8. Altitude alert lights | 25. Cabin pressure gauge |
| 9. Radar altimeter | 26. HSD/MPD |
| 10. Caution/warning panel | 27. BDHF |
| 11. Manual pressure dump | 28. HSD mode selector switches |
| 12. Thrust mgt system | 29. Nav mgt system #1 |
| 13. Engine instrument digital selector | 30. INS mode control |
| 14. Engine fire switches | 31. Radar cursor control & doppler control |
| 15. Engine instruments | 32. AHRS |
| 16. Hydraulic pressure | 33. Fuel control panel |
| 17. Altitude alerting system | 34. Slow/fast approach speed |

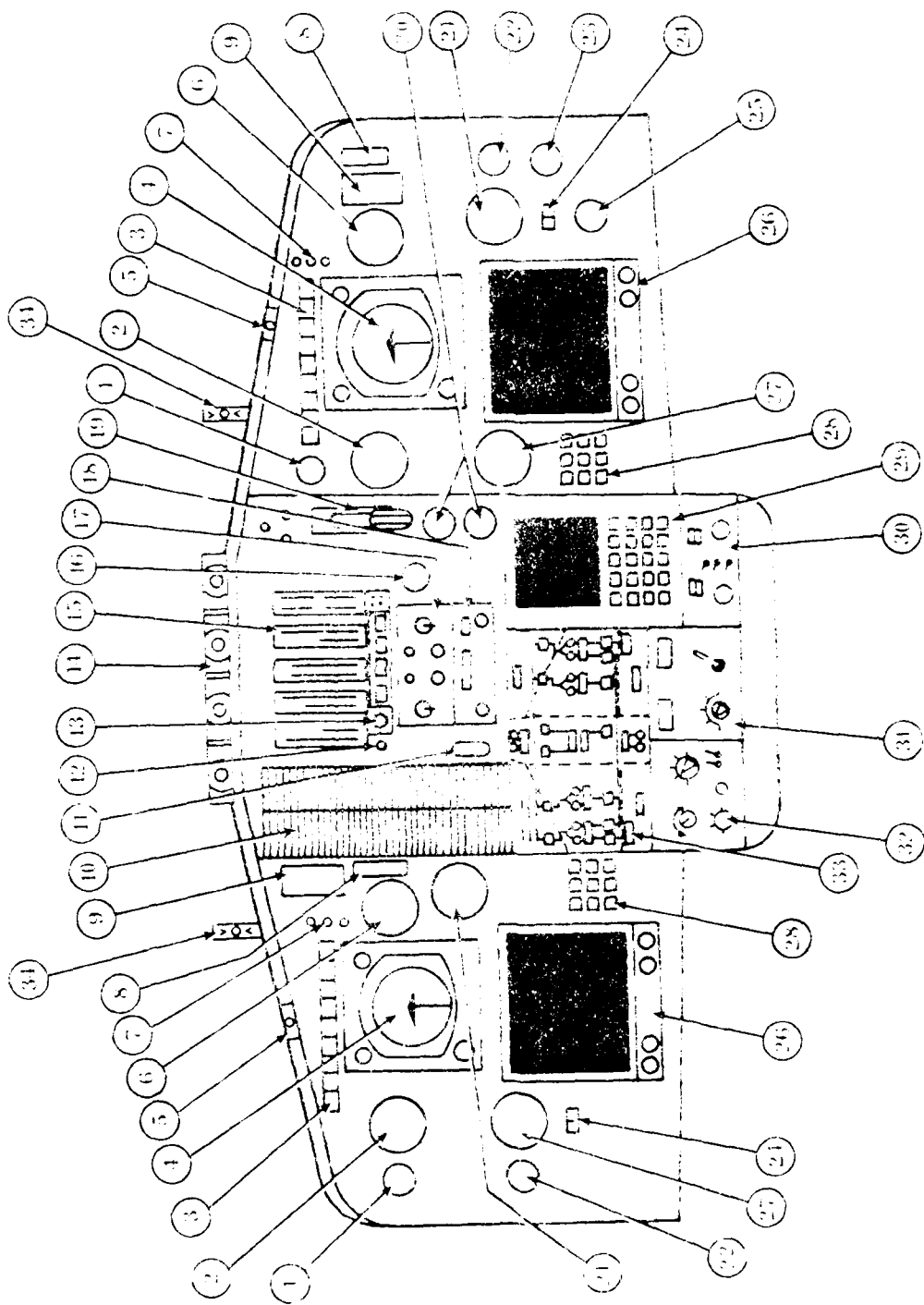


FIGURE 5 FRONT INSTRUMENT PANEL

The aft center console (Figure 4) should be expanded in size to approximately 2 standard ARINC control panels wide and 24 inches long running aft from the throttle quadrant, with the last 8 inches narrowing to one panel width for easier ingress/egress. The height of the console should be approximately 14 inches. The back corners must be constructed so as to preclude injury to the pilots' legs during egress/ingress. The throttles and drag controls are located on the center console approximately even with the yoke along the fore/aft axis. The center console should primarily contain avionics CDUs that must be accessible to both pilots. This includes those CDUs used for communication, navigation and flight control through the autopilot.

The forward center console (Figure 5), formerly called the "fuel panel", must house the fuel control panel and various other avionics CDUs that must be accessible to both pilots as defined by the "Reach Zones".

The pilot's and copilot's side consoles (Figure 10) are space limited to approximately one standard ARINC control panel wide and approximately 11 inches long located outside and abeam each pilot's seat. They should house items requiring access or control by only one pilot, including individual oxygen regulators and individual interphone controls.

The forward boom operator's panel (Figure 11) located at the former navigator's station, must contain controls and displays for use by the boom operator while in the cockpit (communication, oxygen, lights) and some CDUs that are redundant to, or not critical to, locate at the pilots' stations (dedicated INS CDU, HF radio control, accelerometer).

The boom operator's aft station presently offers adequate control and display space and access. In addition to present capabilities, the aft operator's station must allow the boom operator to (1) start and stop fuel flow, (2) preset fuel offload so that offload stops automatically and (3) record and display fuel offloaded during each mission and to each receiver (Ref. 61).

c. INSTRUMENT PANELS. The cockpit instrument panels (Ref. 18) are in three sections; left, center and right. They are dimensioned and installed to provide: (1) necessary over-the-nose visibility from the design eye position, (2) adequate leg room with full rudder and brake operation, (3) unobstructed visibility of the flight and engine instruments, and (4) easy reach by the pilots with their seats in the properly adjusted position. A padded glare shield over the panels protrudes toward the rear to reduce glare on the instruments from outside ambient light.

The left instrument panel contains principally pilot's flight instruments. The center panel contains the aircraft systems and

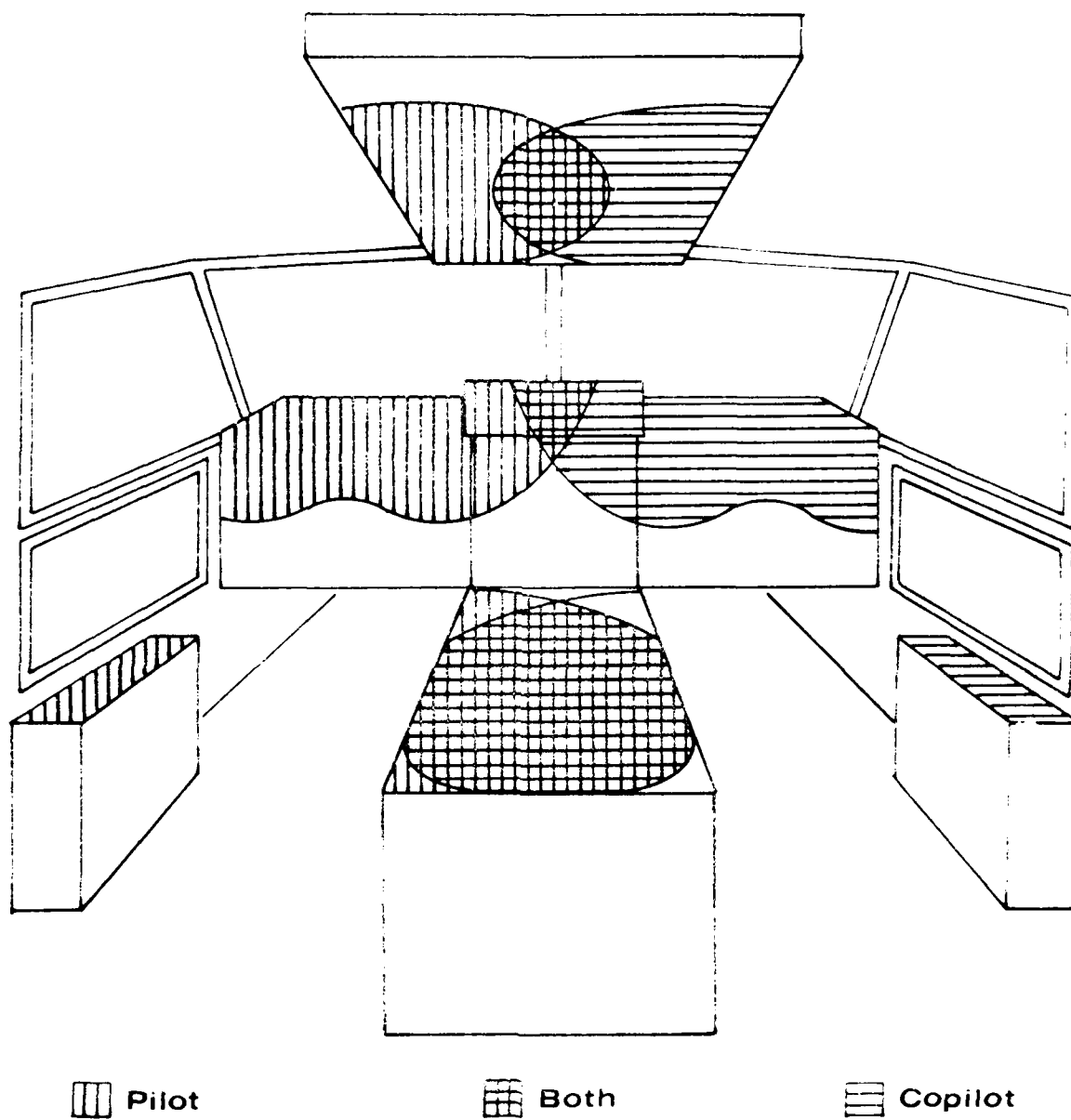


FIGURE 6 REACH ZONE - (Restraint Harness Locked)

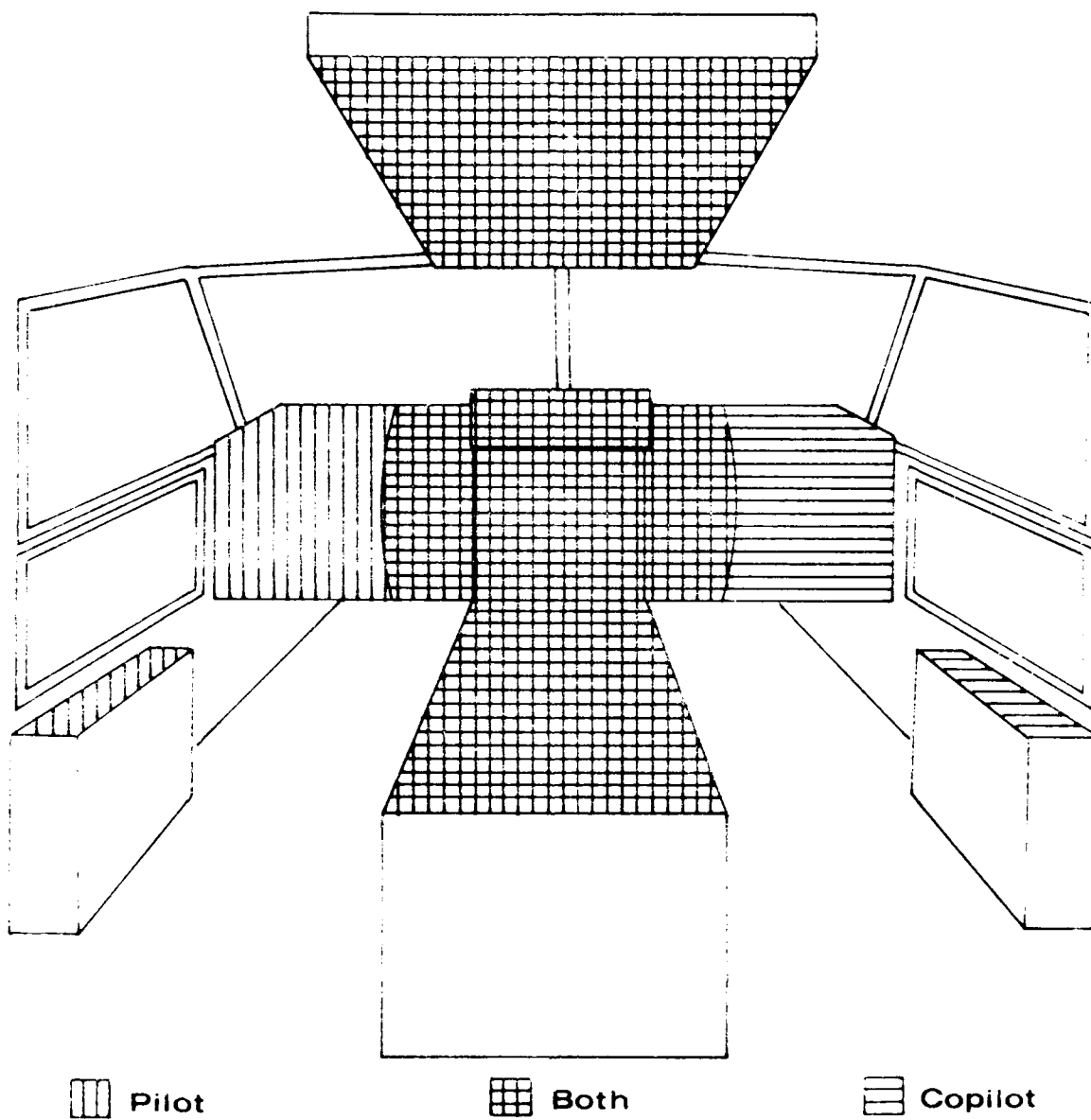


FIGURE 7 REACH ZONE 3 (Restraint Harness Unlocked)

engine performance instruments, a consolidated caution and warning annunciation panel, and landing gear control and position indicators. The right panel contains principally copilot's flight instruments. The instrument panels are gray and the glare shield black.

d. WORK AREA. Information contained in aeronautical charts, flight planning publications, and aircraft performance manuals must be readily available for inflight navigation. Precise and intensive preflight planning does not preclude changes of air traffic control clearances or tactical diversions requiring use of these documents. When they are opened or unfolded in the cockpit, half the instrument panel and windsnield are obscured from either pilot's view and accurate plotting of courses or coordinates is virtually impossible. To provide a working area, a table top surface useable by the copilot at his crew station, which will not interfere with full travel of the flight controllers, is highly desirable.

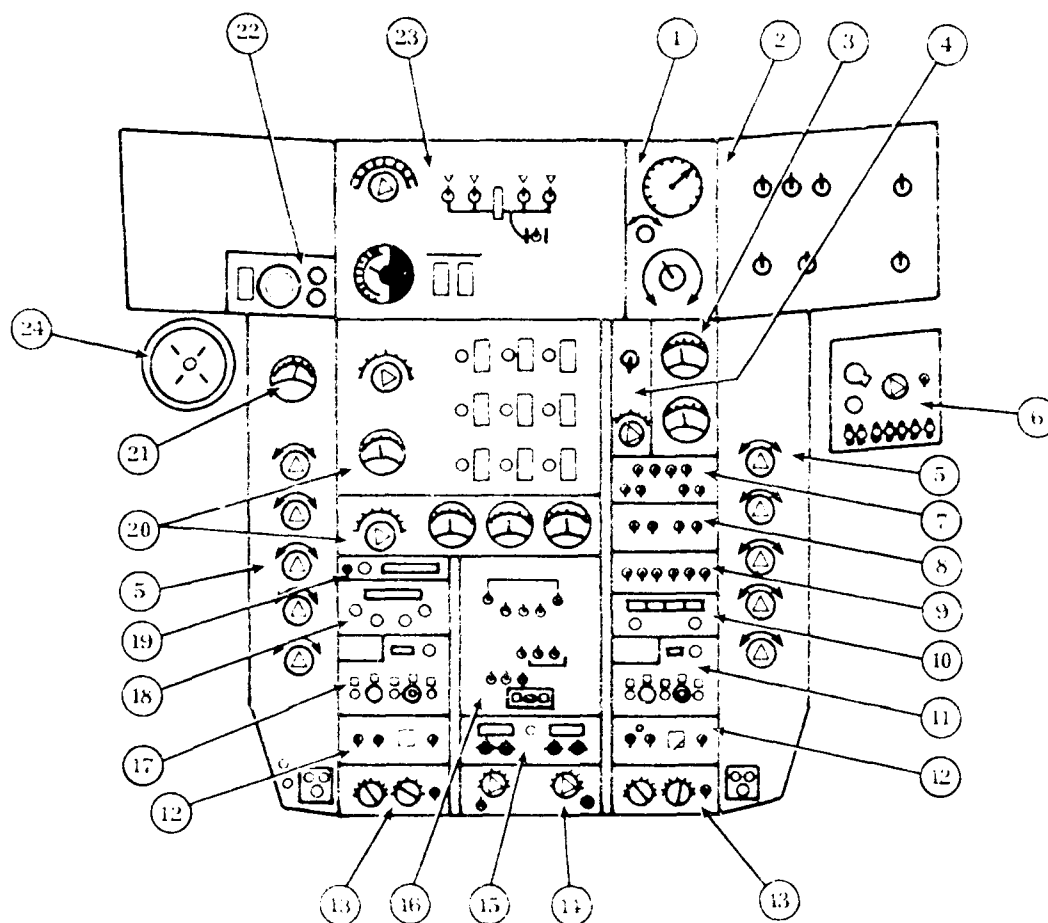
One possible method of providing this workspace is with an extendable/stowable table. While not in use, the table must be stowed near the copilot's seat in a position that will not interfere with ingress, egress or access to the controls. When extended, it must provide a flat surface over the copilot's lap, where publications may be used efficiently without obscuring cockpit visibility. The table, in any position, must not interfere with flight control movement in flight or during ground operations.

e. WORK STORAGE. Binder checklists are typically difficult to hold and are often dropped on the floor or on top of a control or display. A checklist arrangement which alleviated that problem and provides the pilots with pertinent and timely information, is required.

6. REST AREA.

CREW COMFORT. Certain creature comfort features in the design allow more efficient operation by reducing crew fatigue and irritants. Things that the crew can "work around" for short periods become unsafe or inefficient obstacles during a 16 hour crew duty day.

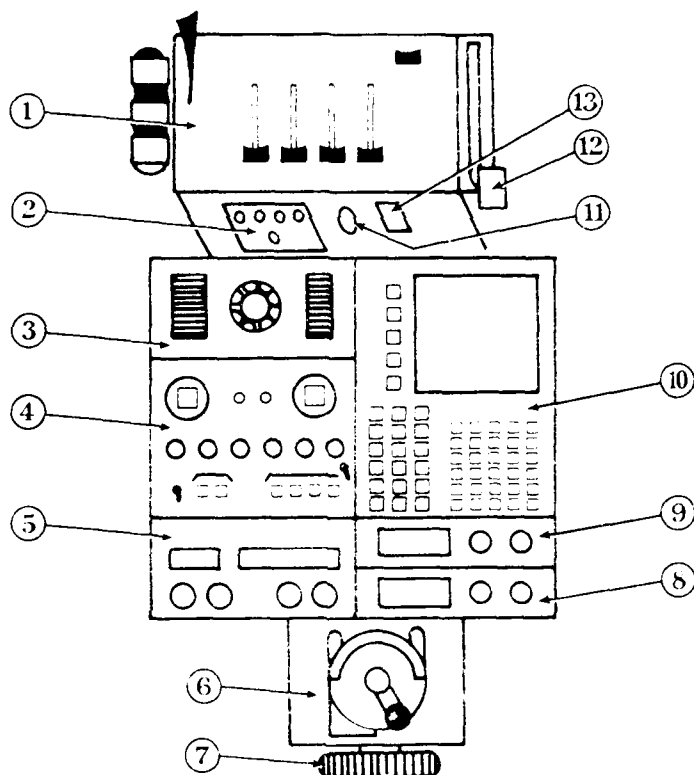
Facilities are provided where an augmented aircrew can eliminate body waste, combat hunger, thirst and fatigue, and maintain a reasonable state of alertness during a crew duty day up to 24 hours in duration. An augmented crew consists of the basic crew plus at least one additional pilot and boom operator (Ref. 19).



- | | |
|----------------------------|-------------------------------------|
| 1. Pressurization panel | 13. Flight director panel |
| 2. Light panel (exterior)* | 14. APN-59 radar |
| 3. Volts and cycles | 15. VHF nav #1 and #2 |
| 4. External power | 16. Autopilot panel |
| 5. Light panel (interior) | 17. UHF #1 comm head |
| 6. APN-69 beacon | 18. HF radio |
| 7. Hydraulic panel | 19. Bell, speaker and antenna panel |
| 8. Instrument power panel | 20. AC-DC power panel |
| 9. Anti-ice panel | 21. Ammeter |
| 10. VHF comm head | 22. Radar pressure |
| 11. UHF #2 comm head | 23. Air-conditioning panel |
| 12. RGA panel | 24. Speaker |

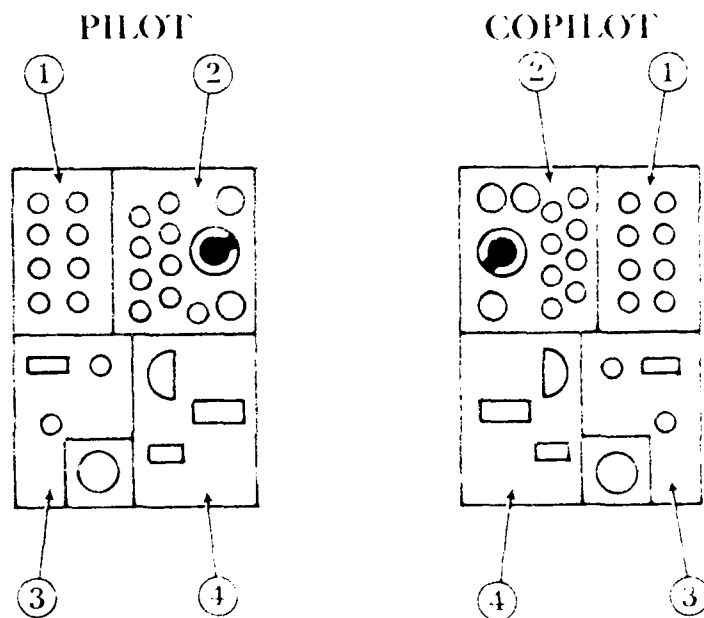
*Note: Nacelle illumination switch is added to present exterior light panel

FIGURE 2 Overhead Panel



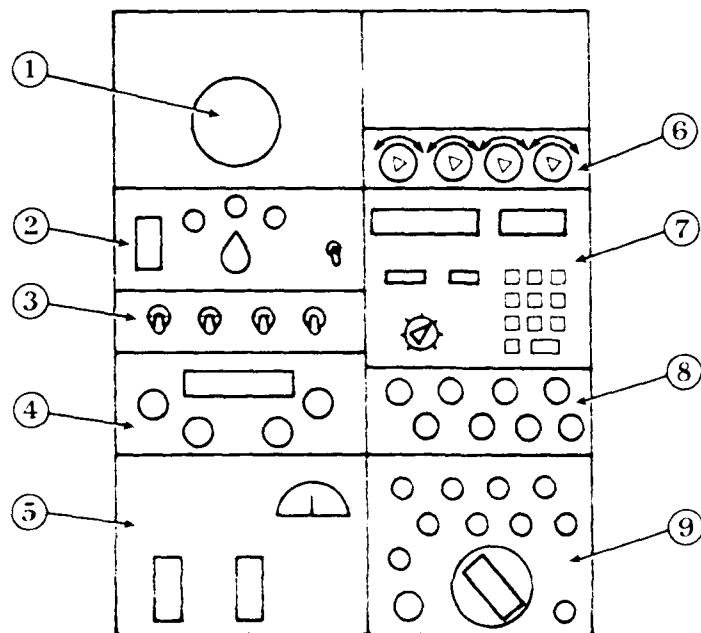
- | | |
|--------------------------|--------------------------------|
| 1. Throttle Quadrant | 8. TACAN #2 |
| 2. Engine Start Switches | 9. TACAN #1 |
| 3. Autopilot Control | 10. Nav Mgt CDU #2 |
| 4. IFF/SIF | 11. Gear Horn Cutout Switch |
| 5. ADF | 12. Stab Trim Cutout Switch |
| 6. Rudder Trim | 13. Wing Flap Control |
| 7. Aileron Trim | 14. Rudder Power Cutout Switch |

FIGURE 9 Aft Center Console



1. Nav monitor
2. AIC-18 interphone control
3. Oxygen nose, dimmer, oxygen quantity, lamp receptacle
4. Oxygen regulator

FIGURE 10 Pilot And Copilot Side Consoles



1. Accelerometer
2. Ciphony control
3. HF transfer and INS
selector switches
4. HF comm
5. Oxygen control
6. Light controls
7. INS control/display unit
8. Nav monitor
9. AIC-18 interphone control

FIGURE 11 Forward Room Operator's Panel

B. INFORMATION (DISPLAY) REQUIREMENTS.

1. GENERAL. It is necessary that the information requirements be addressed in terms which are meaningful to effecting the mission (in contrast to the present practice of identifying only in terms of sensors available. One unique display of a parameter, which is readable to the limits of sensitivity of the sensor, is not necessarily appropriate). Some information, at least by name, will appear in more than one place. It may differ in format, accuracy, sensitivity, and response frequency. Information requirements are tailored to two major categories of interest; namely, Mission Management and Weapon System Control. The major distinction being long term versus short term as well as the scope of interest. Another way of distinguishing between the two is to view Mission Management as the province of assessment, strategy, planning and decision making for accomplishing the mission and to regard the Weapon System Control as the action means for responding to such decisions.

2. MISSION MANAGEMENT. Mission management is the application of the crew system in effecting the mission. It provides for: assessment of progress, as planned, in accomplishing the mission; determination of degree of variation, effect of the deviation and consideration of alternatives. (This is not new, all pilots do it implicitly. What is new is the identification of the area and specific attention to the needs for this function).

In a gross sense, it is necessary to know: (1) If space-time positioning is progressing as planned (that is, is the vehicle at the Latitude/Longitude and altitude planned at the time planned within acceptable tolerances); (2) Have any factors caused a change in the probability of success of the mission; and (3) What alternatives are available if there have been changes affecting probability of success.

a. SPACE-TIME POSITIONING. For mission management, this is primarily a navigation related function. At a minimum the crew must be able to determine their x, y, z position with a time base for comparison to the planned profile against the same time base. Ideally, they should be able to view the time history of planned and actual space-time positions and also the projection for future time. With the constraints of technology and economics applicable to this vehicle it will be necessary to employ a number of sensors and computing devices so as to cover the gamut of requirements from global operation to precise positioning in terminal area. The number of subsystems required is affected not only by the range and accuracy required but is also influenced by factor of reliability and confidence and of the availability of ground or space based aid. As a consequence the crew must manipulate control of a variety of sensors for acquiring data and for combining data. Although a multiplicity of sensors and computers are involved, it is desirable that, from the crew point of view, representation approached a simple single display for satisfying the space-time positioning concern. Based

(12) Distance "10" - display, upon detecting, the distance to a crew specified waypoint as an alphanumeric display readable to ± 0.1 nautical mile.

(13) Ground Map - display, upon demand, a pictorial graphics representation of the terrain around the aircraft. This presented should be selectable by the crew. Two displays are required, one for the pilot and one for the copilot. The displays must be capable of overlaying the present aircraft position and projected flight path. Range and display resolution required are 4 NM to 240 NM range and a resolution of +1 NM.

(14) Pattern Flight - Display upon demand, a crew specified holding pattern, anchor pattern or reserved.

(16) Course and distance - display, upon demand, the true/magnetic course and distance between two consecutive waypoints in a proposed flight plan and/or from aircraft's present position direct to a waypoint in the flight plan or to newly defined waypoint. Readable to one degree and to one tenth of a mile.

4. Input - display logic data, which has been inserted by a crew member via an input device, for crew verification prior to its being loaded into the stored memory. This existing display area is to accept any combination of alphanumeric and correctable or fixed character or segment changes. The display area will accommodate minimum of 30 characters.

17. Actual frequencies - display, open debate, and identification, location and channel number of frequency in all radio navigation and prominent intersection and air fields within the theatre of operations, CONUS, Europe, Africa, etc. This information must be as current as the most recent published U.S. Navy information and available.

Let \mathcal{W} be a set of waypoints at time t . Suppose that, at time t , upon demand, the driver is able to go directly to each waypoint, i.e., the driver can go directly to each waypoint if the driver arrives at a waypoint prior to the waypoint's release. Suppose that, upon demand, the driver can go directly to a company with delivery, i.e., the driver can go directly to a company with delivery if the driver arrives at the company prior to the company's release. In this paper, we consider an expansion of routing, i.e., the driver is able to go directly to a company with delivery, i.e., the driver is able to go directly to a company with delivery upon demand.

[illegible]

(2) Engine (desired but not required) - display, upon demand, a health/life indication for each of the engines, the information to be based upon accumulated hours of operation, normal life expectancy, sensors for oil contamination, sensors for vibration. Should be displayed continuously when reaching a preset limit.

(3) Cabin environment (desired but not required) - display, continuously, hours and minutes of oxygen remaining based upon oxygen consumption rates.

(4) Alternates - display, upon demand, coordinates and identifiers for alternate refueling tracks or alternate recovery sites that are within the capabilities of the aircraft.

(5) Weather - display, upon demand, an indication of weather factors. The display should have the capability of presenting a graphic/symbolic portrait of the weather at crew selectable ranges around the aircraft. The display should have the capability of overlaying aircraft position, flight plan and crew selected waypoints. Range of weather returns will be 4 NM to 240 NM. Resolution will be ± 1 mile with a sector scan or plan position indicator display format. There are two readily visible and independent indicators one for the pilot and one for the copilot. The pilots may have different ranges selected for weather display.

(6) Take off and Landing Data - display, upon demand, all the information required for takeoff or landing. The crew will input the data that is not sensed, i.e., RCR, surface wind on active runway, flap setting, runway temperature, etc. Display is to be in alphanumeric format.

(7) Weight and Balance - display, upon demand, the weight and balance of the aircraft. The crew will input the data that is not sensed (i.e. drogue, cargo and passengers). The basic weight will be pre-programmed. Display is to be in alphanumeric format.

(8) Thrust - display on demand the thrust required for each profile segment, i.e., T/O, climb, cruise (including max range and max endurance), and descent. Thrust commands will be accurate within $\pm .05$ EPR. Associated with this, a digital display on demand will provide optimum altitude, mach/airspeed, time remaining at optimum profile and distance that can be flown at optimum profile. Display upon demand, in digital form, time and distance remaining (readable to \pm one minute and \pm one mile) under present flight conditions.

3. WEAPON SYSTEM CONTROL. Control is a concern with the immediacies necessary to the implementing (effecting) the decisions of tactics and mission. Although the flying of the vehicle

is a dominant concern, there is a substantial workload for communications and management of subsystems associated with effecting mission management plans (action for P.O., landing, traffic control, receiver/tanker hook up, formation flying).

4. VEHICLE CONTROL. This is primarily flight control function. The crew must have the information necessary to direct the flight of the vehicle, to insure safety of flight, to deal with the current aspect of internal and external environment and to respond to the needs of the mission plan. The following display criteria apply:

(1) A/C ATTITUDE. Display continuously, the aircraft body axis rates and position in space with respect to earth references (extension of an earth radius through the aircraft and true north). The display must appear, to the crew, as a continuous graphics display resolvable into the three axes of pitch, roll and yaw. The display must respond accurately (deadbeat) to rotation rates about any axis up to $60^\circ/\text{sec}$. Perceivable position accuracy required is $\pm 1.0^\circ$ in pitch over the range of $\pm 10^\circ$ of pitch and $\pm 2.0^\circ$ pitch beyond $\pm 10^\circ$ of pitch, $\pm 0.5^\circ$ in bank angle in the range of $\pm 30^\circ$ and 1.0° beyond 30° .

A display is required for each pilot position (pilot and copilot). Center of display must be located on an instrument panel $27" \pm 2"$ from the eye reference point and on the lateral centerline of the crew member to a positional accuracy of $\pm 1.0"$. The central axis of the display, vertical placement, on the panel is to fall within the range of -5° to -25° of horizontal with respect to the eye reference point (Ref. 25). For degraded mode operation, movement of the display to another location on the forward instrument panel available to the pilot's view is acceptable.

(2) FLIGHT DIRECTOR. Display, on demand, computer generated command information. Command steering information must be presented in a form which is unambiguous and be interpretable in terms of roll, pitch and roll. Command steering will be in response to a specific, pilot selectable heading, course or localizer/glide slope. It is response to a computer generated course based upon the flight plan inserted by the crew. Display is required for both pilot and copilot position and is to be individually and independently actuated and controlled. This will allow the pilot, for example, to select command steering information while the copilot may select command steering to a preselected course. A continuous display of the flight Director will exist in readily visible area of the reveal area for the crew member when the eye point is behind the display. Sensitivity of the command must be at least 0.005° movement for a commanded rotation change of 0.1° . (Note: This does not require nor does it prohibit integrated cue).

Display to indicate which pilot or copilot is coupled to the information must be readily available.

(3) FLIGHT PATH. While attitude and flight Director displays are the primary action displays, the information necessary to determine desired action comes from supporting displays. One broad class are those which provide information (short term) about the flight path being effected, those paths possible, the desired or required paths and the limits of safety. Flight Path Angle (FPA) is defined as the angle between the horizontal plane and the flight path (in a vertical plane) of the aircraft (Ref. 21). FPA is desirable although not required. If used it is to be displayed upon demand, to either or both pilots. It is also to be displayed in continuous graphic fashion superimposed on the attitude display. The indication is to be a shape coded mark which translates vertically with respect to the horizontal reference on the attitude display. The displacement from the reference line is proportional to the FPA with movement above the line indicating climb and below the line indicating descent. Displacement is to be not less than 0.030 inches per degree of FPA. This is to be positioned to the right side of the attitude display (as viewed by the pilot). Display should be damped so that FPA response rate is similar to pitch response rate displayed under similar circumstances.

(4) SPEED. Display, continuously, at each pilot position Calibrated Airspeed (CAS) (Ref. 22) True Airspeed (TAS), Groundspeed (GS) and MACH. (Ref. 23). The CAS and Mach information are co-located immediately to the left of attitude on the main instrument panel with it's horizontal axis aligned with that of the attitude to a tolerance of $\pm 0.1^\circ$. TAS and GS are to be co-located in the lower left corner of the multi-mode Horizontal Situation Display (HSD). CAS and MACH must be presented in graphics format which may be augmented by alphanumeric readouts. The display scales may be vertical or round. TAS is to be represented by an alphanumeric readout. The values associated with maximum structural limitations must be indicated on the CAS and MACH displays continuously. Ranges, accuracy and readability are as follows: CAS, 40-150 ± 1.0 knot, 150 to 350 knots at ± 2 knots and 350 to 500 knots at ± 5 knots; MACH, 0.1 to 0.9 at ± 0.01 Mach; TAS and GS 0 to 100 KTAS/KGS at ± 1.0 knot, 100 to 500 KTAS/KGS at ± 2.0 knots. The maximum operating limits of .9 mach or 350 KCAS must be displayed continuously and will be integral to the CAS/mach display. Both primary and back up displays will be on the same instrument.

(5) HEIGHT. Display, continuously, at each pilot position barometric reference altitude (Ref. 24). Display, upon demand, at each pilot position the absolute altitude above the terrain. Each value is to be displayed in graphics format which may be augmented by alphanumeric readouts. Range and accuracy for barometric altitude readability are -1000 ft. to +50,000 ft. .5% for barometric references and .2% for CADC reference but not to exceed $\pm 250'$ of true pressure altitude throughout the flight profile. For the absolute values, 0 to 400 ft. at $\pm 10'$ and 400 to 2500 at $\pm 50'$. The display scales may be vertical or round, at the designer's option. The display(s) are to be located on the main instrument panel to the right of the attitude display

with the barometric located closest to attitude. The horizontal axes should be in alignment with the attitude axis to $\pm 0.1^\circ$. Visual low altitude warning symbol must be provided on this display when the vehicle is below 10,000 feet Mean Sea Level (MSL). The barometric displays must also include barometric pressure in inches of mercury, a selector/reminder indication, (Ref. 25) (Ref. 26), and an indication of reversion to backup/alternate sensors during degraded mode or emergency operation. The selector/reminder display, for each pilot, should indicate aircraft approaching selected altitude when deviation is 1000' or less. There should be an indication aircraft has deviated more than 200' from selected altitude or more than 50' from glide path.

(6) VERTICAL VELOCITY. Display, continuously, at each pilot position the rate of change of altitude (Ref. 27). In order to immediately display pertinent vertical velocity information, the sensor parameters should encompass barometric rate, pitch attitude, acceleration and true airspeed. Proper mixing of these signals provides the pilot with all the advantages in quickness afforded by conventional instantaneous vertical velocity displays with the added advantage of display smoothing in turbulence. The true airspeed signal is used to gain-schedule the pitch gyro and acceleration signals.

(a) The vertical velocity display should:

(1) Provide an instantaneous indication of change in vertical profile of the aircraft.

(2) Be calibrated in feet/minute from zero to $\pm 6,000$.

(3) Be easily readable to within 50 feet/minute between 0 and ± 2000 to within 200 feet/minute between ± 2000 and ± 6000 .

(4) Provide both actual and trend information.

(5) Be located immediately to the right of the display of horizontal situation. The size of the digits, scale, actual indicator and trend indicator should be of sufficient size to be read and interpreted from the pilots' eye position.

(7) ANGLE OF ATTACK (AOA). Display, continuously, to each pilot position the relationship between the wing chord line and the relative wind vector of the aircraft (Ref. 28) (Ref. 29). When determining airspeeds, compensation must be made for fuel usage and offload which change the aircraft weight. Additionally, exact cargo/troop weights are often unknown. Turbulence (causing vertical acceleration), and the angle of bank required for some tactical approaches require a "rule of thumb" increase in airspeed. As a result, continuously accurate computation of maneuvering/approach speed is not practical. An angle-of-attack display is required to relieve the pilots of continuously updating maneuvering airspeed requirements while providing them with a direct readout of the desired angle-of-attack, regardless of changing aircraft weight/performance requirements.

and lift configurations. The presently installed AOA system meets the following criteria.

(a) The AOA display should:

(1) Provide a "normalized" indication to simplify pilot interpretation i.e., digits 0-1.0 indicate percent of lift. Zero indicates the zero lift angle of attack reference (or -4 degrees), while the 1.0 represents 100% of available lift and an angle of attack indication between initial buffet and stall (or +16 degrees).

(2) Show the relationship between the aircraft AOA and the desired AOA for cruise and approach configurations.

(3) Show the aircraft's AOA with respect to the AOA for stall.

(4) Provide actual percent of lift as well as trend information.

(5) Be calibrated to display optimum AOA for for max range, max endurance and approach operation.

(6) Provide AOA indications that are automatically compensated for change in lift configuration up to 30° of flap.

(7) Be located to the left and approximately horizontal with the airspeed indicator, since the information from the two systems is complimentary to each other.

(b) The previously described angle of attack information must be supplemented with an AOA indexer. This unit (one for each pilot) is located on the glare shield, centered along the pilots' normal eye references. The top "V" (red chevron) is illuminated between .625 and 1.0 AOA. The green "on speed" "O" (circle) is illuminated between .55 and .65 AOA. The bottom "Λ" (amber chevron) is illuminated between zero and .575 AOA. A dimmer switch is available on each pilots' AOA indexer. The indexer is easily readable under all ambient light conditions.

(c) An approach index indication is amplified, dampened and then repeated on the attitude director indicator fast/slow deviation pointer when this switch selection is made. The center diamond or "on speed" (normalized AOA) indication represents .6 AOA. The slow index (diamond) represents a .65 AOA while the fast index represents .55 AOA.

(8) FLIGHT CONTROL COORDINATION. Display, continuously, to each pilot position, the status of the coordination between the aircraft's rudders and ailerons. The flight control coordination display should show the magnitude and direction of

the "G" vector on the aircraft. The location should be near and in a vertical plane with the attitude director indicator. An inclinometer or ball-in-a-race display (Ref. 30) is recommended. It should be either in the bottom portion of the ADI, or immediately below the ADI.

(9) HEADING. The heading of the aircraft (selectable by the pilot in relation to magnetic north or true north) should be displayed continuously to each pilot (Ref. 31) (Ref. 32).

(a) An adjustable marker to reference a desired heading should be provided. The adjustable heading marker will also be used to signal heading command for the flight director. The heading marker will be integrated with the horizontal situation display and be adjustable independently from either pilot station.

(b) The heading display should:

(1) Show the actual magnetic/true heading of the aircraft to within 1°.

(2) Be stabilized to provide an instantaneous correct heading.

(3) Be integrated with the horizontal situation displays, the EADI, the flight directors and the flight control system.

(c) The heading display should be located near and in a vertical plane with the horizontal situation.

(10) WIND SHEAR. Actual and referenced true airspeed compared to actual and referenced groundspeed should be continuously displayed to the pilots for use during the final approach and landing phases of flight. These parameters, properly mechanized, will provide the pilot with enough information on wind shear at low altitudes for him to determine if safe operations can be accomplished, e.g., can a safe approach be accomplished and what is the proper indicator airspeed, or should a go-around be executed (Ref. 33) (Ref. 34, Ref. 35). A digital display of the difference between true airspeed and groundspeed, described in the paragraphs on those systems, will provide the pilot with required information for wind-shear detection and airspeed adjustment requirements.

(11) TIME. The following timing information (some of which was previously managed by the navigator) must be displayed to both the pilot and copilot:

(a) Time of day in GMT for navigation and communications with air traffic control and command and control organizations (continuous display).

(b) Tickable elapsed time from takeoff or from a specified enroute navigation waypoint used for computation of groundspeed, turning points, and non-precision approach timing tasks.

(c) Estimated time enroute to any waypoint in memory.

(d) Estimated time of arrival to any waypoint in memory.

(e) A two-window digital time display with the following features is recommended: a 24-hour clock readable to seconds and a hackable elapsed time counter readable in hours, minutes and seconds. The counter should selectively count up or down. The clock should operate continuously from the aircraft battery regardless of the position of the battery switch.

(12) BACK-UP FLIGHT INSTRUMENTS. The pilot's and copilot's flight instrument systems must be designed to operate from independent power sources so that, in the event of power failure, the aircraft can be operated by using one system or the other. Additionally, redundant altitude, attitude, airspeed and heading systems, as discussed in paragraphs on these subjects, are required. If electronic attitude director displays are installed, a third attitude indicator with the following features is highly recommended and is required by Federal Air Regulations (Ref. 36) for certification as an air carrier:

(a) Located plainly visible to both pilots.

(b) Appropriately lighted.

(c) Operative independently of any other attitude indicating system.

(d) Powered from a source independent of the electrical generating system.

(e) Operative without selection after total failure of the electrical generating system.

(f) Continued reliable operation for a minimum of thirty minutes after total failure of the electrical generating system.

(g) Be hardened against predictable EMP.

(13) VEHICLE CONFIGURATION. The displays for vehicle configuration are to be grouped together or may be integrated into one display device.

Wing Flaps. Display, continuously, the position in degrees of the wing flaps. A single indication, is to be located on the main instrument panel so as to be readable by both pilots. Display is to be readable and accurate to ± 2 degrees. During transition the lag from stated accuracy is to be no greater than 0.1 second.

Speed Brakes. Display, continuously, the position of the speed brakes. A single display, readable by both pilots is to be located on the main instrument panel. The display is to indicate that the position is fully extended or fully retracted with a readily distinguishable indication for transition or malfunction.

Landing Gear. Display, continuously, the position and status of the landing gear. A single display, readable by both pilots is to be located on the main instrument panel. The display is to indicate the conditions, fully retracted or fully extended and locked with a readily distinguishable indication for transition or malfunction.

Warning. An alerting display readily readable by both pilots, is to provide a readily distinguishable and attention getting indication when drag devices are not properly aligned with the controls or the thrust-drag condition is improper.

(14) THRUST MANAGEMENT. Display, upon demand, within the propulsion display group, the values of the operating parameters for effecting the thrust management condition selected by the crew, indicating the condition selected. An alphanumeric readout is to present the condition selected, the optimum operating conditions, the operationally controllable parameters and the optimum values of these parameters.

(15) CAUTION AND WARNING. There are many items which could adversely affect the mission, the vehicle, the crew. The effects of malfunctions run the gamut from minor inconvenience to catastrophe. The nature of the malfunction varies in time response from the instantaneous to those which accrue over hours and days. The multitude of displays and annunciators require that special effort be made in the case of alerting and warning signals so as to be attention getting. There is also a priority concern - some malfunctions are life threatening and require an immediate response. A small level down in priority in the potentially life threatening situation where the required response is not quite as immediate. Others pose threats of minor distraction, extreme workload, high risk landings and compromised performance. Those of the most urgent, life threatening character require separate unique alerting modes which are consistent from one vehicle to another. Fire and imminent collision fall in this category.

Fire. A flashing red light in the handle of the engine/wheelwell fire extinguisher is to provide the alerting signal to the crew whenever a fire occurs in the engine, nacelle or wheelwell areas. The light must be of sufficient intensity and contrast so as to be readily visible under high ambient illumination conditions. The alerting signal must also operate through the Caution and Warning System.

Collision. A single indication readable by both pilots is desirable. If used it must provide an alerting signal and display for proximity warning and collision avoidance. This, while normally "blanked" must be in an 'armed' or ready status at all times when the vehicle is airborne. The alerting signal must also operate through the Caution and Warning System.

Caution and Warning. "Master" indications for both warning and caution are required for all sensed failures or malfunctions. This is to be effected using two signal lights located centrally in front of each pilot. The intensity must be such that each is readily seen under high ambient light levels. The Master Caution and Warning lights must each incorporate a push actuated switch so that when lighted a push will extinguish it. The Master Caution and Warning Lights, when activated, must stay illuminated until the malfunction is corrected or until the crewman pushes the switch to extinguish it. Each of the lights must respond to an activating signal and correction of the malfunction. Each must be capable of being individually extinguishable by either pilot (Ref. 37) (Ref. 38). Light redundancy is needed to preclude total Master Signal light failure.

(a) The caution and warning panel should:

(1) Illuminate in conjunction with the master caution light but extinguish only when malfunction has been corrected.

(2) Be color coded between cautionary and more serious (warning) systems.

(3) Have a circuit testing system which illuminates all the individual caution and warning lights as well as the master caution lights.

(4) Be readable in direct sunlight.

(5) Be dimmable for night operation.

(6) Consist of one individual dedicated light (redundant lighting to preclude outage) for each system or system failure.

(7) Provide a green annunciator for anti-ice usage. This light will not trigger the "Master" light.

The nomenclature for those lights is:

1 OIL PRESS	3 OIL PRESS
2 OIL PRESS	4 OIL PRESS
CABIN PRESS	AHRS FAIL
ELEC CAB HOT	SWITCH DC BUS
AC FAULT	FUEL DUMP
DET ATT	DET ATT
A/P CYRO	DET INST PWR

PLT FDI09 PWR
 A/P DISC
 COMPARE GS
 COMPARE RGA
 COMPARE ALT
 1 RGA FAIL/OP
 1 INS FAIL
 1 INS HOT
 1 MSN CMPTR
 INS DIST 10 NM
 RDR PRESS
 EXT PWR DOOR
 1 HYD HOT
 2 HYD HOT
 1 HYD PUMP
 2 HYD PUMP
 FUEL PRESS
 LEADING FLAP
 C G
 COMPARE ATT
 ACDS

CPLT FDI09 PWR
 COMPARE LOC
 COMPARE COMP
 DC FAULT
 DOPP MEM
 2 RGA FAIL/OP
 2 INS FAIL
 2 INS HOT
 2 MSN CMPTR
 IFF MODE IV
 BATT CHG TR
 Q INLET HEAT
 3 HYD HOT
 4 HYD HOT
 3 HYD PUMP
 4 HYD PUMP
 RES BRAKE
 BOOM UNLATCH
 CARGO DOOR
 ENG ANTI-ICE
 FUEL QUAN

(b) Some systems require a warning annunciation which is either separate from or in addition to the master caution and consolidated caution and warning panel. These other dedicated warnings include:

(1) Visual and aural gear unsafe warning. These consist of a red light in the landing gear handle which illuminates and a warning horn which sounds when any engine power lever is moved to the idle position without the gear being down and locked. Additionally, dedicated indicators are necessary to show the up, in-transit, or down position of each gear individually and continuously.

(2) Visual and aural wing flap power control warning. This consists of an intermittent horn which sounds when engine power is increased above 93% RPM with the aircraft on the ground, the landing gear down and the wing flaps fully retracted; or wing flaps set at or beyond 40 degrees; or the outboard leading edge flaps are not fully retracted; or speed brakes are deployed.

(3) Visual and aural altitude reminder. This consists of a digital reminder of planned altitude to the nearest 100 feet, and a continuous aural signal and visual light signal when approaching or departing that altitude.

(4) Visual AC and DC power indicators for trouble-shooting systems and further identification of failures. These consist of lights that illuminate to indicate open circuits, generator failures or synchronize cycles.

(5) Visual engine fire warning lights which illuminate when an overheat condition around the engine occurs.

(6) Aural pilot activated system (bell) to alert the crew and passengers of imminent danger such as bail out, ditching or crash landing.

(16) LIGHTING. Lighting must be responsive to all display viewing conditions. Three conditions, listed in ascending order of severity are: (1) a clear or partly cloudy sky with the sun incident on the display over the pilot's shoulder; (2) a low visibility diffuse surround luminance of 10,000 Foot-Lamberts like that experienced in haze, light mist or near the tops of clouds; and (3) sunlight incident through the aircraft windscreen just over the instrument panel glare shield and in the general vicinity of the direction in which the instrument is viewed by an air crew member.

The orientation of installed aircraft instruments must be such that direct specular (i.e., mirror type) reflections of light sources enhance the perceived legibility under this viewing condition. The solution is to either block (or attenuate) the field of view in which the sun is located or increase display luminance to compensate for the apparent increase in display background luminance.

b. VEHICLE PERFORMANCE/STATUS (ADVISORY).

(1) PROPULSION. Indications of aircraft engine performance must be continuously displayed to the pilots, so that proper and timely operational and aircraft maneuvering decisions can be made. Therefore, a display that time-shares engine performance with other information is not acceptable. The engine instrument display system should:

(a) Continuously provide a scaled display (trend information) of each of the following parameters for each engine: EPR, RPM, AGT, Fuel Flow, Oil Pressure and Hydraulic Pressure for each system. This information must be presented on vertical linear scales of a thermometer style. EPR, RPM, AGT and fuel flow will be grouped in a horizontal row with like parameters adjacent.

(b) Provide alphanumeric readout of each of the parameters, either as dedicated readouts or a selectable readout by engine, i.e., all four EPRs or fuel flows simultaneously for comparison. Digital readouts must be at least 0.20 inches in height.

(c) Provide a commanded EPR indication on the scale display and a dedicated or selectable readout for engine performance based upon optimum engine performance at given pressure altitude, temperature, and weight as a function of pilot setting. Flight envelope, i.e., takeoff, climb, cruise, max endurance, max range, descent.

(d) Provide color coded markings indicating minimum, maximum and intermediate operating limitations.

(e) Fit within a space or not larger than 6" wide, 6" high, and 7 inches deep (behind panel).

(f) Be readable and legible in all ambient light conditions, i.e., controllable for night-time operations and visible under worst case viewing conditions (See paragraph IV, b, 3, a, 16 on page 60).

(g) Be easily read and interpreted to the accuracy required for each parameter.

(h) Be grouped together on the center instrument panel in a position easily viewable by each pilot.

(i) Be integrated with a caution and warning annunciator system that will alert the pilots of any malfunction or exceeded parameters.

(j) Have a print-out capability to provide the low-ground maintenance personnel with a paper print-out record of system performance at a pre-determined frequency (i.e. oil pressure every 30 minutes) and a record of system malfunction/failure (Ref. 61).

(k) Be scaled and color coded as follows:

SPK

Min - 1.1

Max - 3.2

Expand - 2.13 - 2.85

Color - Green entire scale.

Min scale with green line at 2.85.

Temp

Min - 70

Max - 110

Expand - 80 - 100

Color - Green 70 - 100

Min scale with green line at 100

Max scale with green line at 100 - 110 and 110 - 120

Oil Pressure

Min - 10

Max - 70

Expand - 10 - 60

Color - Green 10 - 60

Min scale with green line at 60

Max scale with green line at 60 - 70

Min scale with green line at 60

Min - 0
Max - 10000
expand - 2000 - 4000
Color - Green entire scale

Oil Pressure PSI
Min - 0
Max - 60
expand - 35 - 50
Color - Red 0 - 35
 Amber 35 - 40
 Green 40 - 50
 Red Above 50

Hydraulic Pressure - Left and Right System (PSI X 1000) (2 lines)
Min - 0
Max - 3500
Expand - 2400 - 3100
Color - Red Below 2000
 Green 2000 - 3050
 Red Above 3050

Hydraulic Pressure - Reserve Brake (1 line)
Min - 0
Max - 3500
Expand - 1400 - 3100
Color - Red 0 - 1000
 Amber 1000 - 1300
 Green 1300 - 3050
 Red Above 3050

Hydraulic Pressure - Rudder Power (1 line)
Min - 0
Max - 3100
Expand - 2400 - 3100
Color - Red 0 - 800
 Green 800 - 1175
 Red 1175 - 2400
 Amber 2400 - 2800
 Green 2800 - 3050
 Red Above 3050

4. ELECTRICAL. The pilot must have the capability to control voltage, frequency, and relative system load on each system on a manual or selective basis. Both controls and displays for the electrical system can be located on the overhead console, or a light/warning annunciation connected to the main display of the consolidated warning panel is required for malfunction or failure.

Failure of electrical equipment which causes circuit breakers to include circuits should be readily identifiable. While the presently installed circuit breakers provide adequate circuit protection, identification and recognition of the individual breakers is marginal. Installation of labeled circuit breakers would improve this crew system.

(3) Hydrazine. Indication of hydrazine system pressure and quantity should be available to the pilot in a continuous and selective manner. Alert/warning announcement is required for malfunctions or failures.

(4) Fuel. Fuel quantity, in pounds, known by hot and in total amount, and fuel flow in pounds per hour during flight must be displayed to the pilots at all times and should be located on the forward center console. The fuel panel must:

(a) Be no larger than 10 3/4" wide by 7 1/2" high including mounting.

(b) Be capable of providing the same functions and information as the present AC-130A fuel panel. This will include 15 gauges, 15 valve switches, 15 pump switches, 5 low pressure lights, the fuel pump control, and a flow diagram depicting fuel routing within the aircraft.

(c) Include the "boom engage" indicator light.

(d) Display the actual aircraft center of gravity in relation to center of gravity limitations.

(e) Incorporate lighting controls to make the displays readable under high ambient lighting conditions.

(f) Provide signals to the master caution and master warning systems. Indicator lights to be provided for fuel pressure at the engine manifold and for fuel quantity.

(g) A numeric fuel flow diagram which shows the direction and routing of fuel to the engine tanks. The flow diagram as changes in fuel flow occur.

(h) Location of the aircraft showing the relative position of the various fuel tanks.

(i) A readout of fuel transferred to an individual receiver, which is resettable by the pilots.

(j) A readout of total fuel transferred to all aircraft (sum of all transferred fuel), which is resettable by the pilots.

(d) A system to alert the pilot whenever any main fuel tank has less than 9000 pounds of fuel without all tank to engine manifold valves open, all main tank boost pumps turned on, and the landing gear down.

(l) A system to alert the pilot whenever the main fuel tank level falls below 20% capacity and the engines are not being fed from the tank to engine manifold configuration.

(m) A system to alert the pilot whenever the center wing tank fuel quantity falls below 20% capacity and both override pumps are not on and at least one boost pump per engine is not on.

(n) A system to alert the pilot of low fuel quantity whenever the fuel remaining is less than the fuel required to destination (plus alternate if designated) at preprogrammed TAS (\pm winds) plus one hour.

(5) PRESSURIZATION. The presently installed system meets the following criteria. Cabin altitude may be selected between -1000 to 10,000 feet by the pilots, after which the selected cabin altitude is automatically maintained with a maximum altitude differential limit of 8.6 psi. Emergency depressurization controls are provided. Cabin altitude is displayed at all times. The rate of change of cabin altitude is controllable between 50 and 2000 feet per minute. Alert/warning annunciation is provided for malfunctions and for indication of cabin altitude above 12,000 feet MSL.

(6) AIR CONDITIONING. Cockpit and cabin temperature controls are installed, however, actual temperatures should be displayed.

(7) OXYGEN. On the presently installed system the oxygen system quantity (0-3 liters) is displayed at all times. Individual oxygen regulator pressure as well as normal and emergency oxygen flow are provided and displayed on demand at all crew stations plus two passenger stations near the cargo door. Alert/warning annunciation is provided on the regulator panel in case oxygen flow stops for any reason. Seven portable oxygen bottles, ten portable oxygen bottle brackets and six oxygen recharging outlets are provided. Quick donning oxygen masks should be provided at the pilot's and copilot's stations as well as an indication of oxygen remaining (in hours and minutes) at present rate of use. If the oxygen system is not in use, the hours and minutes of oxygen remaining will be displayed as if one person were using oxygen with 100% selected.

c. SPACE-TIME.

(1) HORIZONTAL SITUATION. Display to each of the pilot positions the information necessary to remain oriented with regard to true/magnetic north; heading vs ground track; heading

to desired track; desired flight plan; geographical features; weather; other aircraft (in the formation or receiver aircraft); runway and nav aids and the required maneuvering (in a horizontal plane). The information is for the control of the vehicle in the short term context.

Display the relevant data for control of flight path in a horizontal plane. A separate display is required for each pilot position. The center axis of the display is to be located on an instrument panel $27" \pm 2"$ from the eye reference point and laterally on the center line of the crew member to a positional accuracy of $\pm 1.0"$. Additionally its lateral alignment with the attitude indication must be within $\pm 0.1"$. The vertical placement must be immediately below the attitude display. For degraded mode operation, display at another location on the forward instrument panel is acceptable.

The information to be displayed falls into three categories; display continuously, display only upon demand, display either continuously or upon demand according to the designers option. The following must be continuously displayed. Magnetic or true heading (preferably at top center of display) of the aircraft to a readability of $\pm 1.0^\circ$ in a symbolic graphic format. Desired true or magnetic course (preferably at the top right corner of display), actual distance and time at present airspeed (preferably at the top left corner of display) to a crew designated reference point (TACAN, waypoint, localizer) to a readability of $\pm 1.0'$ in a digital format, for the angular information and to a readability of ± 0.1 mile up to 99 miles and ± 1 mile thereafter for the distance information in a digital format and ± 1 second up to 1 hour and ± 1 minute thereafter. Groundspeed and true airspeed will also be displayed continuously in the lower left corner of the display.

The horizontal situation display should provide the pilots with the capability to remain oriented in relation to flight plan elements (e.g., Nav aids, Designated points of latitude/longitude, Designated points defined as a bearing/distance from another waypoint including the AKCP); waypoints of interest off the flight plan (e.g., emergency airfields, areas of threat, airway crossing points); areas of severe weather; earth terrain features; other aircraft in formation, and receiver aircraft for air refueling rendezvous.

The electro-mechanical DS. portion (Ref. 39) of the FD-109 system, presently installed, does not provide the flexibility to display all the required information efficiently and effectively. Therefore, an electronic display capable of displaying multiple formats and sensor information is required.

It is essential that the position of the aircraft in relation to specific selected points be displayed to both the pilot and copilot at all times in flight. The horizontal situation includes:

aircraft position, heading, course, course deviation, drift, bearing, and distance information, all presented with the accuracy necessary to accomplish a given flight maneuver profile.

The horizontal situation display (HSD) must provide the pilots with the capability to selectively obtain any or all of the information listed above. It must be displayed in such a way that the horizontal position of the aircraft relative to the earth terrain features, navigation waypoints, weather cells, formation aircraft and receiver aircraft, as appropriate, is accurate and intuitively obvious to an appropriately trained pilot.

Each pilot must have the capability to individually and independently select the following for display on his HSD: Navigation mode (e.g., individual sensor, computed/processed), format (e.g., standard HSI, electronic map) and special functions (e.g., radar overlay, north-up or track-up, clutter, range/scale of the display).

A color display is extremely desirable for ease of interpretation. The HSI format on the HSD should have the following features: two bearing pointers with tails, compass rose with lubber line, heading select knob, actual alphanumeric heading readout, course set knob, course-selected readout, failure indications for the components and the navigation source, and other standard HSI features (e.g., course deviation, To/From, DME, aircraft symbol, course arrow, heading marker). A continuous readout of groundspeed and true airspeed is required on the HSI format.

The HSD must be integrated with the navigation management system and the flight director. It must have the capability to display information which has been placed in the mission/navigation computer in such a way that the pilots can accomplish the mission scenario (e.g., flight plans placed into the navigation management system should be graphically displayed on the HSD). The computer should have the capability to provide display and review of the entire flight plan within seconds. No selected information may take longer than one minute for display. One method of displaying required information on the HSD was developed for purposes of verifying these criteria and is shown in Appendix B.

While some of the information should be integrated into a single CDU (HSD) for each pilot, some information should be displayed separately (e.g., RMI, BDHI), to reduce clutter and provide a redundant/back-up source of horizontal information. To provide bearing and distance information additional to that displayed on the HSD for normal operations and for purposes of redundancy/back-up during degraded mode operation, a BDHI should be installed on the pilot's and copilot's flight instrument panel. The pilots should have the capability to individually select the source or navigation sensor from which each of the bearing pointers are receiving their signal. Radar will be displayed on the

HSD as a pilot selection. The radar imagery will either overlay the symbol generated flight plan route (not HSI format) or will be displayed independently. Display modes will include (individually, not simultaneously): weather, APN 69 beacon, surface terrain, or skin paint. Only one display mode is available to both pilots at a time. However, each pilot may select different ranges at the same time. Range selections will be 4, 12, 20, 40, 80, 160, 240 Nautical Miles. Weather warning will be displayed on HSD anytime a severe weather cell is detected on radar. Display of radar will be sector scan or PPI as selected by pilots using "track up" mode only.

C. CONTROL REQUIREMENTS.

1. GENERAL. Control is used in the broad context within this document to include not only the manipulation of stick and rudder and other physical activities but the manipulation, control and direction of data processing and information flow among the displays, computers and automation equipment. In a sense then control is synonymous with "Command." Within this context of complete and total control a dichotomy can be defined (as was done in display) of long term (Mission) and short term (Vehicle).

Control may be effected by a variety of mechanisms (e.g., stick, wheel, rudder pedal, rotating knob, rotating multiple position switch, toggle switches, sliding devices, push button). Care must be taken in the selection/design to insure that esthetic considerations do not interfere with identification, location and operation. Push buttons must have sufficient "throw" and detent so as to provide positive tactile feedback through gloves. Spacing between adjacent devices must accommodate 95 percentile pilots wearing gloves. The possibility of inadvertent actuation must be guarded against. Toggle switches and rotary switches must have sufficient movement and detent action to provide positive tactile feedback. Symmetry of shape and position is undesirable. Shape coding and position coding is highly desirable for positive identification. All spring loaded devices must accommodate the wide range of strength to be expected.

2. MISSION. In mission control, the crew is concerned with actions, decisions, controls in the context of effect or impact upon the ultimate outcome of the mission. In this context then it is those controls which are operative for long term response which are of concern. Obviously the actual manipulation (switch, knob) will be quick but the effect is long term (e.g., engage altitude hold and set a desired altitude). Navigation in general falls in this category (while ILS may be categorized as a Nav aid it is a short term consideration and is discussed under Weapon System Control). Weather and Threat are environmental conditions the effect of which is generally long term.

a. SPACE-TIME POSITIONING. The controls necessary for determining (and cross checking) space-time positioning and comparing with the plan should be clustered and located in a primary reach zone. Following are the criteria:

(1) All sensors (or sensing systems) are to be individually and selectively controllable by either pilot.

(2) Controls should be categorized more nearly with equipment.

(3) To use or move the information you must select the sensor, move the data to the place to be manipulated and then move the data to one or more places for display.

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4. Altitude. A fast erecting display of pitch and bank altitude is required under 14 CFR. In case of failure, provision must be made to switch on to back-up or switch to alternate display. If an electronic altitude display is installed, a separate back-up system capable of operating for 30 minutes on 28 volt aircraft (aircraft battery power only) and at least 10 minutes without an external power source in order to permit emergency recovery of the aircraft, would be necessary.

b. FLIGHT DIRECTOR. Control of the Flight Director will involve the selecting of primary modes and submodes and the indication to the system of desired criteria. Primary modes are:

- (1) PARADOX
- (2) POINT TO POINT
- (3) RENE ZWILL
- (4) APPROACH
- (5) LUNAR SEA

Two modes permit selection of the following reference criteria:

- (1) Angle of Attack
- (2) Heading
- (3) A. (Pitch) and Yaw
- (4) Roll
- (5) Airspeed
- (6) Altitude
- (7) Pitch, Yaw, Roll Angle

Information to the display must be totally compatible with the information to the automatic flight control system. (Inter- and intra- and inter- and A/C AGI for dampening effect on sensitive mode display systems, etc.). The crew member must be provided the capability to select inputs for guidance from the following modes: TACAN, VOR, LORAN, INS, ADF. A sub control mode should permit the crew member to select A/C response characteristics. The display must be able to select a display mode for manual control, automatic operation and lighting the display. The display must be able to be turned on and off. The display must be indicated in the cockpit in the cockpit normal switch panel. The display system must be capable of independent display action. The display must be able to be turned on the automatic flight control system and the display must override authority.

[illegible]

d. HEADING. The heading indication of the aircraft must be selectable as to the use of magnetic north (for typical operation with navigation aids) or true north (for over water, high latitude, etc.). The selection must control the inputs to all heading indicators so that they present, simultaneously, true north as a reference or magnetic north as a reference.

A redundant source for heading is available from the AHRS and two INS systems. The source to be used must be independently selectable by each pilot. If both AHRS and INS heading systems are in use (i.e. AHRS-pilot, INS-copilot) and true heading mode is selected, the heading signals from the AHRS will be modified (with INS information) to supply true heading signals to selected displays. The heading reference of "magnetic" or "true" must be clearly annunciated to both pilots.

e. WAYPOINTS. Waypoints to be stored in non-erasable memory are: prestored nav aids, intersections or airfields. Additional waypoints may be inserted by the crew into a memory which they may later change or delete. Waypoints inserted by the crew will have a computer assigned identifier (e.g., LL1, LL2). These identifiers may be further expanded by the crew (by the addition of words (e.g., LL1/COAST OUT, LL2/FIR, LL3/MARY)). Waypoints may be inserted by the crew in terms of bearing and distance from a waypoint already defined. In that event the bearing and distance notation will be retained. All waypoints will be defined by the computer in terms of longitude/latitude. The flight plan can be modified at any time to go directly from the aircraft present position to any identified waypoint. Waypoint capacity will be a minimum of 50 waypoints, recallable or reusable and non-volatile. However, a guarded erase feature will erase an unwanted flight plan from memory. A typical flight plan will be programmed on a portable memory device at a location remote from the aircraft (i.e. base operations). The programmed flight plan will be complete with desired waypoints, desired altitudes, forecast winds, desired TAS, weight and balance computations, fuel plan and TOLD computations. The programmed portable memory device (i.e. cassette or floppy disc) will be carried to the aircraft by the crew and inserted into the mission management computer memory. Subsequently the crew may modify the flight plan as desired, using the nav management system in the aircraft. After a flight plan has been flown, a print-out capability will provide the crew with a paper print-out of the actual flight plan as flown, complete with ATA, altitudes and fuel log. (Ref. 61)

4. NAVIGATION. The pilot/machine interface for controlling the navigation sensors should meet the following criteria. It should provide for:

a. Some amount of redundancy in event of navigation management CDU failure, i.e., a second CDU and a dedicated INS control head.

b. Some amount of redundancy in event of processor or black box failure.

c. The correct operation of the controls which is intuitively obvious to the pilot.

d. All sensors to be individually and selectively controllable by the pilot.

e. Automatic tuning of TACAN navigation radios (with clearly visible annunciation of automatic tuning) along an inertial flight track.

f. Capability for both the pilot and copilot to individually and selectively monitor (receive) aural identification signals from any or all VOR/ILS, TACAN, ADF, and Marker beacon transmitters, simultaneously on both headsets and cockpit speakers and to independently adjust each input volume.

g. Capability to adjust the light intensity of the displays either automatically or manually to satisfy ambient light conditions.

h. Redundant controls for the INS may be outside the normal reach envelop of the pilots, providing they are readily accessible to someone else on the flight deck.

i. Increasing the number and type of navigation sensors interfaced on the control/display unit for increased flexibility, with minimal change in size and operation of the overall navigation system.

5. COMMUNICATION. The pilot/machine interface for controlling communications radio information has the necessity for simultaneous communication (transmitting, receiving, monitoring) with several agencies on different frequencies which requires an easy, accurate method of tuning each R/T unit, readily identifying the frequencies tuned, and identifying which frequencies are being monitored. Dedicated control heads for each communication radio, of the type presently installed, are generally sufficient for the mission. However, the addition of VHF communications capability, relocation of the dedicated control heads and additional audio monitoring and volume control capability is required. The system should have:

a. Dedicated control heads located where either pilot can readily and easily operate them.

b. Capability for both the pilot and copilot to individually and selectively monitor (receive) transmissions on any or all communications radios simultaneously on both headset and cockpit speakers.

c. Capability for both the pilot and copilot to simultaneously tune separate communications radios.

d. Capability for both the pilot and copilot to individually and selectively transmit on separate communications radios (one radio per pilot at a time) without interference.

e. Capability to provide UHF/DF information to the navigation system.

f. Proper operation of controls in a manner which is intuitively obvious to the crew member.

g. Capability to preset and recall/tune at least 20 UHF channels that correspond to predetermined frequencies.

h. Individual volume adjustment controls for each radio at each interphone panel position.

i. Complete monitoring and transmitting capability, similar to the pilots', at the forward and aft boom stations.

j. Capability to tune/operate the HF radio from the forward boom station as well as from the pilots' position.

k. Intraplane communications between all crew position, without broadcasting outside the aircraft, except to ground handling personnel through an external receptacle for use on the parking ramp. (Interphone)

l. Capability to communicate with receivers' crew through both aircrafts' interphone systems, when connected together for refueling, without broadcasting outside the two aircraft. (Boom engaged interphone)

m. An interphone feature which, when activated, allows any crew member to override all other communications reception within the aircraft. (CALL)

n. Capability for crew members to transmit to passengers in the cabin and enough speaker output so that the passengers can receive the transmissions. (Public address)

o. Selective Call (SEL/CAL) feature must be available for HF operations.

6. CONTROL.

a. FLIGHT. The presently installed flight control system (Ref. 40) meets the following criteria. Primary flight controls for manual operation must consist of a control column (with a control wheel) and rudder pedal. Switches and displays are required for selection and activation of the various modes and functions of the flight control system. All controls must be centrally located or duplicated for pilot and copilot.

b. AUTOMATIC. Engagement of automatic flight control must be separately selectable for each axis with positive

facile feedback. A single "emergency disconnect" switch for the autopilot must be located on the control wheel. It must have a high visibility contrasting color and be of the "press-to-activate" type. An infinite revolution, rotating knob, located on the center console, may be used for "trim" input commands to the automatic system.

(2) MAN/AIL. A control wheel must be provided for pitch and roll control. Switches to be mounted on the control wheel are: trim, a propeller, braking marker flow, rotational ground engage and autopilot disengage. Each switch is to be spring loaded to a neutral position with a press to operate mode. The control wheel may be mounted on a floor column or extended from the panel. It must be positioned such that it does not interfere with vision. The control must displace easily and smoothly. Braking force must not exceed seven pounds in either direction. Force to displace in either axis should increase linearly with displacement. Two rudder pedals are to provide yaw control while in the air and the braking while on the ground. They are to be dimensionable for the 5th to the 95th percentile male pilot. The primary positioning is under the instrument panels. In addition to the "trim wheel" with trim switch on the outside handle, there is to be a manually operable pitch trim wheel near the front of the center console. It is to be electrically driven in response to trim commands or capable of being positioned manually by trim input. Wheel is to be solid (no spokes). The trim wheel's position is displayed on a linear scale on the instrument panel. Manual rudder and aileron trim controls are to be located on the aft center console, accessible to both pilots. The indicators for those trim systems are linear scales adjacent to the controls. Manual trim controls may be substituted with electric trim controls. In this case, back up trim controls are required.

(3) THROTTLES. The propeller and aileron system needs the throttle control. Propeller control is to be provided with a single control knob on the center console and operable by either pilot. One control knob is to be provided for each engine. The knob is to be located on the console, with one hand, all throttles to be operable by each pilot individually. Normal operating range is to be an arc of not greater than 90°. Positive tactile indication is to be provided for all stops corresponding to Full Military Power and Maximum Cruise. Positive restriction at the Minimum Power position is to be provided to prevent inadvertent engine failure.

(4) LIGHTING. The display, controls, indices and placards are to be illuminated, as far as possible, under all ambient lighting conditions. Sect. 4.1.4.4.1. Sect. 4.1.4.4.2. Capability to illuminate light intensity of the displays either automatically or manually to satisfy ambient light conditions is required.

(5) INDICATORS. The display and controls are to be illuminated. The display and controls are to be illuminated at least as well as the crew to replace and replace. Instrument panel floor

lights, console and overall cockpit flood lights, lighted instrument approach plate holders should be pilot selectable and adjustable in intensity and color (red and white). Map reading lights, mounted permanently or selectively, to illuminate an area in the pilot's, copilot's and boom operator's laps without being hand held, are required and must be individually controllable. Individual reading lights at each additional crew seat are necessary and must be shielded/filtered so as to minimize the effect on the pilots' night vision adaptation and to also prohibit direct reflections of lights from cockpit windows (Ref. 44). Cabin flood lights are necessary. The white cabin lights must provide adequate illumination at floor level, with and without cargo, so that intricate tasks can be performed without hand held illuminating devices.

Instrument and panel lighting must be controllable to meet all types of lighting conditions and flying situations. The lighting system should exhibit uniformity in both brightness and color. Display indicia (symbols, formats, readouts, labels, etc.) should be completely legible at normal operating levels, not at maximum gain where they are typically checked (i.e., uniformly illuminated except where information is intentionally highlighted). Light emitting displays should have an ambient light sensor to automatically adjust the intensity of the display during changing ambient light conditions. On CRT displays the symbology, including digits, must be legible at both maximum and minimum ambient light levels. Warning, caution and advisory lights when energized should be readable in direct sunlight. Adequate dimming should be provided for these annunciators to compensate for the ambient light level.

In order to provide maximum flexibility to operate in a "see and avoid" training environment, as well as in a "minimum detection", combat support environment, considerable flexibility is necessary for aircrew selection of exterior lights. Standard position/recognition lights, rotating beacons, landing and taxi lights, air refueling underbody, underwing and nacelle illumination lights, receiver pilot director lights, boom marker, and nozzle lights are installed. Control of these exterior lights is provided through position switches on the overhead console and/or the boom operator's station, as appropriate. Indications of the "ON" status of external lights, not visible to the crew, should be provided under appropriate lighting control.

8. FIRE. A separate extinguisher control shall be provided for each engine. It is to be a "T" shaped handle mounted on the glare shield central to the cockpit and accessible easily by either pilot. Each shall be actuated by a single hard pull. The relative placing of the handles shall correspond with the relative position of the engines.

9. ELECTRICAL. Individual selective controls, easily accessible by either pilot, should be provided for on-off control of all AC and DC systems. Although they will primarily be used only

during ground operation, they provide the pilot capability to selectively power up or down system during malfunctions or emergencies. An automatic changeover feature to select an alternate or emergency source of power when a primary system fails is required. The changeover should include all critical equipment and as much non-critical equipment as the alternate source can safely power. A ground or airborne operational turbine (GTPU) is required as a selectable source of power. Circuit breakers should be readily accessible, and operable with gloved hands.

13. HYDRAULIC. Normal operation of the entire hydraulic system should be controlled with simple on-off switches easily accessible by either pilot, located on the overhead console, or automatically through engine operation.

a. BRAC/LIFT. Drag/Lift Controllers. Controls for all surge drag devices should be accessible to both pilots and be integrated into a minimum number of cockpit controls. Positive control to easily identifiable positions for wing flaps and speed brakes is required. Spoilers are deflected with aileron movement.

b. FLAPS. A pivoting arm lever movable through a 90° arc shall be provided on the console for control of flaps. It shall allow selection of flap positions from 0° to 60° extension. Full up shall correspond to 8° flap and the displacement shall be linear for flap positioning. The flap position is displayed on two position indicators located on the center instrument panel. They are accurate within 2° and more than a 4° spread indicates a failure of the main flap drive system.

c. SPOILERS. Four spoilers, installed as pairs on the upper surface of each wing, deflect 0° to 60° as a part of the lateral control system depending upon control wheel movement.

d. SPEED BRAKES. The spoilers can be used as speed brakes by positioning a lever on the center console. The speed brake position corresponds to the position of the lever and is displayed on the center console adjacent to the control.

e. FUEL. Fuel valve, pump and tank selector controls, located on the forward center console, should provide routine control and pressure when needed for engine operation and to provide an unattended fuel condition, relocate fuel prior to air-to-air transfer, and provide routing and pressure for fuel transfer. Also, fuel dump control and fuel transfer indicator control (from buttons) are required.

f. BRAKES. The present brake control system (too pressure on the rudder pedals) is adequate, however, an anti-skid system and a brake reverse are highly desirable.

14. STEERING. Steering of the nosewheel is presently provided only by the pilot through a handwheel. The system is adequate, however, steering should be provided to both the pilot and

copilot through two handwheels or a rudder operated system with a selectable engage-disengage control on the control wheels.

15. PRESSURIZATION. Pressurization controls should be located on the overhead console and provide for adjustment of cockpit/cabin altitude at a selected rate to that desired for cruise, landing field elevation or inflight depressurization.

16. OXYGEN. The crew should be able to selectively don and use the quick don (pilots') masks at any altitude. The control should provide normal or 100% oxygen, on/off pressure control and emergency pressure breathing control.

17. AIR CONDITIONING. Air conditioning controls on the overhead console (cooling, heating, ventilation, humidification and decontamination) should be selectable and adjustable by the pilots or be settable by the pilots to operate automatically. Cabin temperature should also be adjustable from the cabin.

18. CAUTION AND WARNING. The system should have a circuit testing system which illuminates all the individual caution and warning lights as well as the master caution lights.

19. RADAR. The radar control should be located on the overhead panel, easily accessible to both pilots. The controls must include: ON/OFF; STANDBY; WEATHER; WEATHER/CONTOUR; MAP (SEARCH); BEACON; TILT; GAIN; GYRO STABILIZED ON/OFF; PLAN POSITION INDICATOR/SECTOR SCAN.

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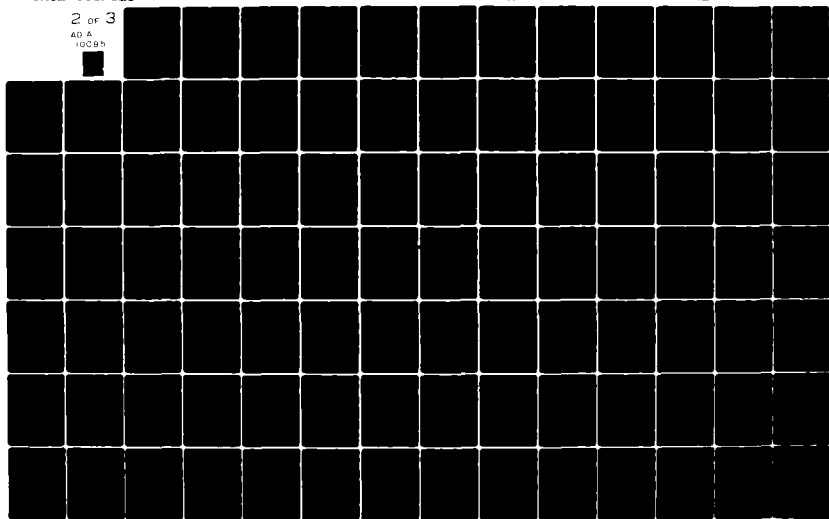
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SECTION V

TEST AND MEASUREMENT

Tests and measurements are the processes for acquiring data which are descriptive of physical characteristics or provide information on performance characteristics.

The data acquired can be compared to standards for determining compliance or non-compliance with those standards.

For decision making purposes on complex systems, the greatest weakness is that no laboratory test has been devised that takes into account all significant factors and produces an output adequately descriptive of the total performance capability of the system.

This section addresses the alternative, the use of batteries of tests. These batteries of tests attempt to measure all of the known factors which are significant to the determination of the ultimate suitability of the system.

A. GENERAL. Test techniques can run the gamut from paper and pencil tests on a simple component to a full blown flight test program on a complete system. The general approach advocated is one of progressive screening pursued on two levels. On one level, components and subsystems must be demonstrated to comply with appropriate standards. On the other level the total system must be demonstrated to satisfy the mission needs. Figure 12 illustrates the characteristics of progressive testing. As tests become more sophisticated, the cost of the test and the time to perform the test increase. While confidence in the results also increases with the increased sophistication, the ability to respond to design variations decreases and the speed of response for examining problems decrease.

TEST CONTINUUM

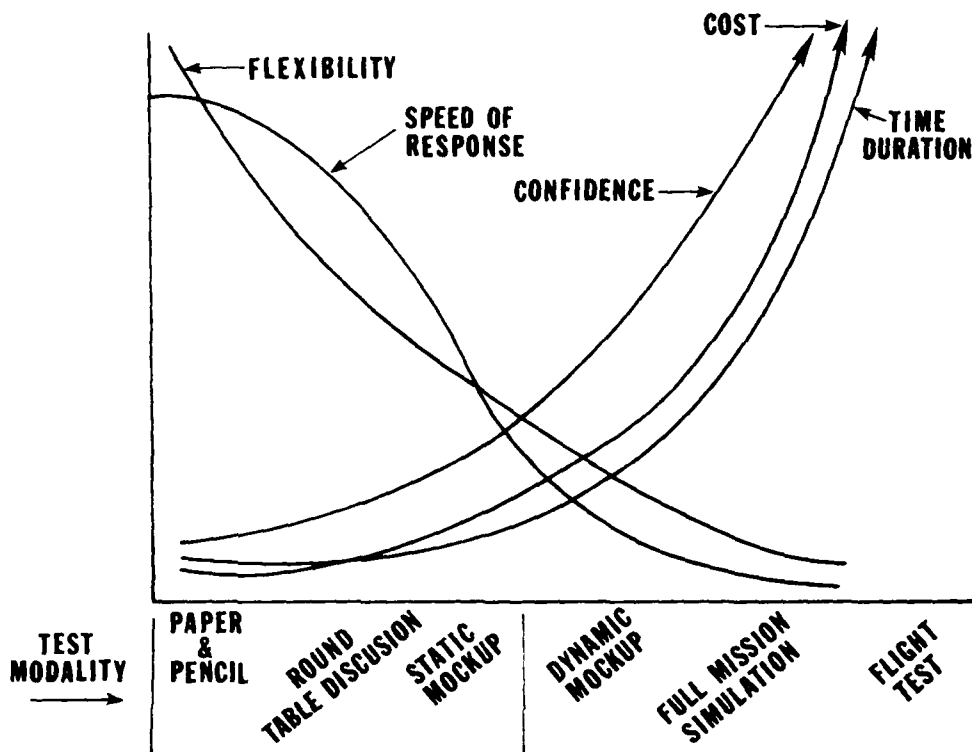


FIGURE 13 Test Continuum

The testing sequence recommended is to use the more economical techniques initially and, as these are satisfied, move on to the more extensive procedures. All test data must be available to the assessment teams.

B. **PHYSICAL.** The physical characteristics of the crew system design should conform to well known and well documented human engineering principles. Conformance to these should be ascertained by examination and measurement during the development. These include such factors as workspace layout, shape coding of controls, spring force in switches, "Throw" of a switch, spacing of graduations on a dial. It would be well to review these in the final design. Undergraduate training in such degree fields as Engineering Psychology, Human Engineering, and Industrial Engineering should provide the basic skills necessary for review in harmony with standard handbooks. More complex issues require a specifically structured consideration, the most challenging of which is lighting and its effects upon vision.

Some of the physical characteristics of the cockpit lend themselves to or are more appropriately considered in the Performance Measurement (e.g., crew ingress/egress).

1. COMPONENTS. Reliance is placed upon contractor supplied data. For each component or subsystem complete data is to be supplied on its physical and functional characteristics including all data on tests performed to show compliance with the individual equipment specifications. This must include size, weight, power requirements, radiation characteristics, vibrational characteristics, temperature characteristics and human factors characteristics.

2. WORKSPACE. Plots of Reach and Vision zones are to be developed for the 5th, 50th and 95th percentile crew members on accurately scaled drawings of the crew stations. The plots must include a plan view and a forward looking view for the flight deck and the crew member view for other work stations. Ingress/egress is to be demonstrated by 5th and 95th percentile crew members. Evaluation will be subjective.

3. CONTROL-DISPLAY LAYOUT. This is a physical measurement of the placement of each control and each display element to determine degree of compliance with any location data specified in Section IV.

4. VISIBILITY. Plots are to be developed of the vision afforded by the windows. The plots are to be in degrees with respect to a longitudinal axis with origin at the eye reference point (Ref. 17) (Ref. 13). These will be examined to determine compliance with criteria specified in Section IV.

5. SEATING. (Ref. 14) Must be adjustable for ingress/egress, including emergency egress, and adjustable for eye reference point, for required inside/outside references (to be made intuitively obvious to the crew member); accommodate required reach zones without readjustments; provide arm rests which accommodate cruise (straight and level) piloting tasks with or without autopilot; be adjustable in four (4) axes (i.e. fore/aft, up/down, side/side and back tilt); firm upper leg and back support which enhances comfort and reduces inherent fatigue of long sitting periods (i.e. 10-15 hours); have resilient support with materials that "breathe" as opposed to plastic like materials which cause hot spots and perspiration; accommodate restraint systems without discomfort; allow complete mobility for piloting tasks including all probable flight maneuvers as well as permitting full scan through all available viewing areas; enhance communications hookup (i.e. seat involved "hung ups", pinched and tangled head set cords); accommodate drinking cups; accommodate a working/writing surface that will not interfere with emergency access to flight controls and will not interfere with any flight control movement; accommodate special crew equipment (i.e. parachutes, exposure suits, helmets, etc.).

6. NOISE. This will be performed only with the simulation and flight test equipment. Each piece of equipment in the crew area is to be turned on (to its normal operating mode). Before and after measurements with a soundmeter must show an increase of no more than 5db of combined noise.

7. LIGHTING. For the lighting evaluation it is essential that a Class A mockup be used (see page 86). All light sources must be presented in a faithful representation of the production design. The mockup is to be used in a room where all external light sources can be controlled from total darkness up to a level representative of high ambient sunlight. With ambient at total darkness and subjects (examiners) in the pilot and copilot seats, the lighting controls are to be cycled throughout the ranges and combinations available. The subjects (examiners) are to scan for reflections in the windows and windscreen which could be misinterpreted as stars, ground lights or other airborne vehicles. All such reflections are to be identified and graphed for comparison with the criteria stated in Section IV. (See page 60, paragraph 16)

With the ambient totally dark, the subjects (examiners) are to adjust comfortable levels for the prime flight instruments and for each of the additional controlled groups of lights. The subjects (examiners) will scan for too bright or too dim indications and for lighting color variations.

a. NIGHT LIGHTING. Activate selected caution, advisory and warning signals during lighting inspection.

Requiring readout by the crew of selected display information from an evaluation checklist assures that all subjects actually attempt to read a representative cross section of the cockpit information portrayed and do not simply assess information as too bright or too dim. The inspection should also involve the identification and activation of controls and switches to evaluate the adequacy of switch and panel lighting. Switches and controls in locations not easily reached or observed are of particular interest. Providing oral directions for setting switches and controls with a follow up to verify the correct setting were achieved would provide a test of the adequacy of this lighting. The setting of communications frequencies and navigation data requires reading night illuminated numeric displays and allows evaluation of data I/O using night lighted control devices. Evaluation of other night lighted displays particularly of the alphanumeric type and any associated control, mode, change, or data entry functions would also be desirable as a means of drawing attention to potential defects of design, layout, or function under the night lighted condition. Assess crew performance in achieving predetermined scenario settings.

When evaluating the effect of reflections from the windscreen, windows, etc., small lighted real-world visual scenes could be used external to the cockpit to act as a backdrop for evaluating

the seriousness of reflections. Such scenes would have to be moved to locations behind reflections a crew member considers objectionable. By varying the luminance levels in the scene, be it ground terrain, cities, airports or star fields and noting when the crew member considers the reflection objectionable, a relationship between real-world observation requirements and the lighting mockup conditions could be established.

b. DAYLIGHT LIGHTING. Evaluation of daylight cockpit lighting is appropriate for determining how shadows cast by the cockpit structure influence the legibility of displayed information and for assessing the problems encountered when the sun is positioned so that it acts as a glare source reducing display legibility. The design effectiveness of window shades, glare shields, sun visors or any other light blocking devices present in the cockpit should be evaluated. The question of legibility arises primarily for light emitting displays such as signal annunciator lights, CRTs, light emissive numeric or alphanumeric readouts, but should also be evaluated if controllable light reflecting displays are present due to the potential degrading influence of shadows or the sun as a glare source. Clearly these displays would have to, as a minimum, present test information formats that can be changed as a function of time to assess the crews ability to correctly read them and to provide realistic crew comments on their subjective legibility and the adequacy of the high end of the luminance setting range.

The glare source used to replicate the sun could be several times the size of the sun, but would have to provide light collimated to simulate a distant light source to enable an adequate evaluation of the shadows and possible reflections it would produce from cockpit surfaces including those of the windows and wind-screen. This is also necessary to adequately simulate the effect of the sun as a glare source in making display readings difficult.

Sources having translucent surfaces illuminated to 10,000fL and placed adjacent to the windows of the cockpit would adequately represent the 10,000fL diffuse surround luminance condition experienced in mist, haze, and near or in clouds.

8. STATIC REVIEW. The crew station(s) will be inspected by a team of specialists assembled for this purpose. This review is for the purpose of ascertaining compliance with the provisions of the AFSC Design Handbook DH 2-2 (Ref. 17) and for soliciting the judgmental expertise assembled in the Review Team. The actual review is to be preceded by a briefing on the design rationale. All comments/observations of the Design Review Team should be submitted in writing.

C. PERFORMANCE MEASUREMENT. The "proof of the pudding" is flying the real thing in a real operation. Performance measurement is to view the proposed cockpit and crew station design in the same context as "proof of pudding" tests. Three major stages are employed - MOCKUP, SIMULATION AND FLIGHT TEST. Each, within the

limits of cost and capability of the stage, is to be a complete representation of employment of the system in a realistic manner. These three stages differ in degree of realism (fidelity of simulation) and in cost, proceeding from the gross (but cheap) Mockup through the more realistic (but more costly) Simulation and Flight Test.

In each, the concern is for determination (prediction) of the effectiveness of the entire complex of crew and equipment when applied against the mission problem. The measurements are intended to indicate the areas of weakness or deficiency and to give some values for use in redesign.

The three stages are sequenced in time. The Mockup occurs first and serves as a check upon proposed concepts prior to committing extensive funding to equipment development and fabrication. The Simulation stage is based upon the Mockup experience and is pursued at a later stage in the system development when data is available on the expected hardware performance and vehicle dynamics. The higher degree of realism in simulation testing provides refined data on performance expectations, pin points weak spots and provides a higher confidence level in the decision to progress to the more expensive realism of flight testing. The Flight Test stage can be pursued in a flight test vehicle such as the Total In-Flight Simulator (TIFS) or in a prototype of the actual vehicle. With the authenticity of actual equipment operating in the airborne environment and exercised against the design scenario, the highest degree of realism is achieved short of applying actual production systems in real world situations. The degree of confidence in the design and in decisions to proceed with production are of the highest caliber when supported by Flight Test.

1. DYNAMIC REVIEW. A mockup of a proposed design provides the earliest opportunity to view the potential solution in a system context. Gross inadequacies of placement and relationships are easily discernable. Initial judgment can be made as to the suitability of the design when considered for mission application. It provides an opportunity to screen out gross weakness at a relatively low cost and prior to commitment of expensive fabrication of prototype equipment.

This test develops the time dimension of the mission and examines features of the crew interface within and external to the vehicle. Prime method is through role playing by subject crews and experimenters. Using sorties extracted from the Design Scenario, (to produce an Evaluation Scenario) flight crews are to engage in a role playing simulation of the sortie, sequencing through pre-flight, the sortie "flight", post flight debriefing, post flight questionnaires and post flight interviews. The scenario to be employed in the Dynamic Review encompasses all types of mission tasks, meteorological conditions, SKE (station keeping) formations, instrument approaches, and hostile environmental conditions which the tanker would be expected to encounter. It also

includes multi-tanker as well as single-tanker sorties. The scenario is divided into three sorties. It is described in detail in Appendix A. Measurement is based primarily upon observations by the experimenters, the use of questionnaires, and interview by the experimenters. The crew activities are recorded on video tape and all verbal communication is tape recorded for subsequent review by the experimenters. Preliminary assessment of workload is accomplished by means of having the crew perform time estimations as secondary tasks while flying the mission.

a. PROCEDURE. Each of the subject crews are to receive identical treatment starting with the Initial Briefing and proceeding through Ground School, Preflight, Flight, Postflight and Interview.

Initial Briefing. There is a need to explain the role playing concept, the limitations of the mockup in simulating the problem, the general objectives of the experiment, an overview of the agenda, expectations of the subjects and convey an appreciation for the place and value of this test in the context of the total program.

Ground School. The purpose of ground school is to acquaint the crew with the function and operation of the equipment which they will encounter in the crew stations. They are to be given diagrams showing the layout and position of every display and control. A specific briefing is to be given on each device which is new or which differs from that with which they are familiar. Information sheets and diagrams are to be provided for each of these devices.

The crew is informed that the only way it can reasonably evaluate each design is for each person to project themselves totally into the mission. This entails imagining that they are involved in an actual mission. They must respond to and make necessary communications, twist knobs, flip switches, monitor instruments, manipulate the controls and in general act and conduct themselves as if they were really flying a mission. Substantial contribution on their part is necessary since there is no functioning simulation of instruments or controls, other than a functional communication system.

Preflight. This should be conducted by an experimenter who is thoroughly familiar with such real life events and should approximate the realism of preflight briefings normally used in an operational squadron. The particular sortie to be flown is one of the legs from the Design Scenario (Appendix A). The selection of sorties for the crews and the sequencing should be a balanced experimental design as in Table 1.

Flight. The crew enters the mockup and proceeds through all normal checklists, procedures and communications for flying the sortie. Although switches, knobs, etc., may not function the crew member must touch and simulate operation in order to evaluate

system control requirement and control placement/location. This process of evaluation enhances subject participation in role playing which in turn allows subjects to evaluate the validity of the mission scenario. Experimenters are to perform role playing functions for tower, command center, other aircraft and other radios in their respective role playing capacities.

Time durations should conform to the mission plan. An experimenter/observer is to be in the cab during this flight for the purpose of administering timing tasks to the crew members, for assessing workload and for general observation. A time estimation technique is used for one indication of workload (Ref. 45) (Ref. 46). This is initiated by the experimenter in the cab at the times indicated in the scenario. The experimenter also is to use the Experimenters Workload Assessment Form (Appendix D) during the Flight.

Postflight. This is the concluding episode for role playing purposes and is a transition into a questionnaire phase. Each crew member is to fill out a questionnaire (shown in Appendix B).

Interview. Each crew member is to be interviewed to elicit comments, criticisms, suggestions and other responses with regard to his personal assessment of the mission, the tasks, working relationships, crew duties, workload, errors, cautions, concerns, crew system design concepts and the experimental procedure.

b. SUBJECTS. The subjects for this test must be several complete crews from operational squadrons of SAC who are currently assigned to the KC-135 aircraft. A minimum of three crews and preferably nine crews must be used representing low, medium and high experience levels.

c. EXPERIMENTER'S SCRIPT. The Experimenter's Script (see glossary) is used by the experimenters to "drive" the experiment and to assure that all data crews are exposed to the same mission situations and time constraints. In actual practice, the experiments must also respond knowledgeably to communications initiated by the aircrew. Thus the experimenter(s) must be intimately familiar with communication within the aircraft environment and with the mission to be flown. In addition to the "words" to drive the experiment, staging for each particular experiment appears with the script along the time line (e.g., initiate engine failure, make radar blip appear, radio transmitter weak and scratchy, monitor information being placed into the nav management system). While the script words remain the same for each system evaluated, the staging will change according to the peculiarities of the system. The Experimenter's Script is included as Appendix C.

d. SUMMATION. For each group of crews on location for the test, the final activity is a group meeting with the experimenters. Open discussion (questions, comments) is to be developed for the exchange of views. The resolving of uncertainties

TABLE 1
SUBJECT SCHEDULING

Crew Number	<u>Day 1</u>		<u>Day 2</u>		<u>Day 3</u>	
	Run	Leg	Run	Leg	Run	Leg
1	1	1	3	3	2	2
2	2	3	1	2	3	1
3	3	2	2	1	1	3
4	1	1	3	3	2	2
5	2	3	1	2	3	1
6	3	2	2	1	1	3
7	1	1	3	3	2	2
8	2	3	1	2	3	1
9	3	2	2	1	1	3

and for the final summation of each crew member's opinion. Each crew member is to fill out eight questionnaire sheets (Appendix E) summarizing his overall reaction to the proposed design.

D. EQUIPMENT. Test techniques can run the gamut from paper and pencil tests and interviews to full blown flight test programs. Consequently the equipment to be employed could encompass virtually every known measuring device. In the discussion of equipment, only the unique and highly specialized needs will be addressed.

1. MOCKUPS. A full scale mockup of the crew areas is a prime requirement for early viewing of interactive factors of the design concept. As the design process progresses more detailed examinations can be effected but the demands upon the accuracy, fidelity and completeness of the mockup change. Consequently three categories of mockups are defined to provide for these differing requirements. These are defined as follows:

Class A - The highest degree of accuracy and fidelity is embodied in this class. All dimensions are accurate to ± 0.1 ". The wind-screen, windows, canopies or other transparencies are either the actual final design or are fabricated of the actual material to the actual dimensions. They must have the identical characteristics of transmission, reflection and distortion. All control or input elements movable in the final design must have the movement faithfully represented (control wheel, rudder pedals, switches, knobs, levers, etc.).

Surface texture, reflectance, color must accurately reflect the intended production characteristics. The total lighting system must be included to permit the full spectrum of capabilities to be demonstrated. The communications system, as perceived by the crew, must be a faithful representation of the final design. In so far as is practicable the actual equipment is to be used (e.g. seats, charts, throttles, rudder pedals, etc.).

The crew station must be complete with walls and closures so as to permit control of ambient light and sound.

Class B - A medium degree of fidelity is considered appropriate. Structural dimensions should be accurate to ± 0.5 " and component placement accurate to ± 0.25 ". The communications system must simulate correctly the operational concept. Windows and canopy structure should be represented but substitute materials may be used. Three dimensional aspects of control devices and display devices should be represented by any suitable medium. Instrument faces and placards may be drawings or pictures.

Class C - The simplest with the minimum degree of fidelity is generally approximations of structure and surfaces with inexpensive material. The mockup may be fabricated of inexpensive material (e.g., foam core, cardboard, plywood). All surfaces,

windows, furnishing, consoles, controls, display panels, instruments which are to be used or viewed by the crew are to be represented. Pictorial (e.g., photo stat, picture, line drawing) representation of instruments, placards, knobs, switches, annunciators will suffice. Control wheels, sticks, throttles, pedals must be represented in their true three dimensional configurations. Overall compartment dimensions and the location and sizes of windows, surfaces, doors, furnishings must be accurate to ± 1.5 inch. Control devices (switches, knobs, etc.) instruments, placards must be dimensionally accurate in area coverage and location to $\pm 1/4$ inch. The communication systems must be functionally simulated (i.e., the intercom must operate and radio communication must be faithfully simulated to the crew by use of role playing positions external to the mockup). External to the mockup there must be provision for role playing experimenters representing communication stations as tower, command center, other aircraft, etc.

2. SIMULATOR. Full mission simulation is a goal. Full scale representation of the crew areas and equipment is necessary. This could be accomplished by upgrading of the mockup if suitable basic design and construction has been employed. Geometric relations and structural dimensions must be accurate to ± 0.5 inches.

All equipment (indicators, switches, controls, annunciators, lights, seats, etc.) must be functional as perceived by the crew. Internal operation of the subsystems can be through simulation (as opposed to coupling in operational equipment). Simulation of real world visual characteristics is necessary; motion of the cab is not necessary. The equations of motion are to be those predicted for the vehicle (or the actual equations if the vehicle exists).

3. TESTS

1. WORKLOAD. A major concern is the demands made upon the crew. There is a need to know if their mission performance will be degraded because there is more to do than they can handle. There is also a concern for emergency conditions. If degraded mode causes an increase in workload beyond their capability to respond, the results could be catastrophic. Direct measurement is not a viable option (a state of the art limitation at this time). The alternatives to be employed are: the use of questionnaires for subjective data; the observation by the experimenters and the use of secondary tasks for indirect measurement.

The use of a secondary task is based upon the concept that an increase in the mental effort required to perform the primary task will produce a decrement in performance on the secondary task but no decrement in performance of the primary task (flying the mission). The secondary task is designed to permit measurement of performance and to be as non-intrusive as possible. Deteriorating performance on the secondary task is an indication that the primary task is demanding more attention. The secondary task which is to be used is a Time Estimation technique (Ref. 46).

a. TIME ESTIMATION. The subject will be asked to produce time estimates during one of the training flights and during all three days of data collection. Baseline time estimates will be taken prior to each collection session. The estimates taken during the data collection days will be used for data analysis. The time estimation procedures will be the same in both cases with the exception that the baseline estimates will be taken without a concurrent primary task.

The time estimation procedures are as follows: The cockpit (inside) experimenter will turn on an auditory tone and flashing red indicator light which signals each pilot to begin estimating. They do this by pressing a response key, and terminate their estimates by pressing the key a second time. The auditory tone is only a momentary signal to augment the flashing red light which remains functioning until the timing task is terminated by the subject crew member. The pilot's response key will be located on the left hand side of the yoke; the copilot's key will be located on the right hand side of the yoke. These keys will start and stop their respective reaction timers located at the inside experimenter's station. The experimenter will record the pilot's and copilot's estimate and reset the timers for the next trial.

b. QUESTIONNAIRE. Stress tolerance (or work capacity) is quite variable throughout the population. One reason for the selections of crews with a gamut of experience, and for the numbers on the scale is to provide an adequate sample of the ranges of stress tolerance to be expected in the operational environment. Each person can, to some degree, provide information on the degree of stress he experienced and its relationship to his maximum tolerance. Questionnaires are used to elicit this information. The confidence level to be placed upon these is directly relatable to the sophistication of the experiment. With a low fidelity mockup that data is indicative, while inflight experience is highly credible.

Each crew member is to be given a questionnaire (Appendix E) following each "flight". The same questionnaire is to be used for Mockup, Simulation and Flight Test.

c. OBSERVATION. In the realm of subjective evaluation is the observation of crew behavior by the experimenters. The background experience and training of the experimenters is the basis for credibility in their judgment of degree of stress being experienced and the factors which precipitate overload. Their observations have higher objective credibility than the self assessment of a crew member. They are based chiefly on observed behavior and cannot include any of the internalized factors included in self assessment.

Each experimenter is to be given a questionnaire (Appendix E) for each "flight". The same questionnaire is to be used for Mockup, Simulation and Flight Test. Experimenter should key in anticipated highs where a numerical rating of each crew member should be observed.

SECTION VI

ASSESSMENT

Assessment is the estimating or judging of character and value. Validation is official sanction, confirmation or approval.

This section addresses the process by which assessment is effected and validation established.

Determination of the suitability and acceptability of a specific crew system design cannot be done by some simple, direct measurement. Batteries of tests are used to determine compliance with explicitly stated criteria, standards or specifications. They elicit data about characteristics and performance. Although they may be extensive, comprehensive and expensive, they are not the final word. Decisions must involve human judgment.

There is a high probability that all significant variables have NOT been identified, characterized and measured.

Final determination of the Yes/No question is, as always, a judgment. It is the role of management to effect the judgment and it is a role of researchers, developers and scientists to give credible data and confidence through testing programs and through procedures to augment the incompleteness or inadequacies of testing programs. Section VI addresses these procedures.

A. GENERAL. Tests are methods for measuring specific characteristics. When used with criteria or standards (i.e., specifications) they provide a screening process for identifying unacceptable features. However, there is no assurance, when applying a battery of tests, that every significant variable has been identified and measured. In a system as complex as crew systems you can be sure that this is the case.

A desirable alternative to the individual measurements is one, all encompassing technique, a measurement protocol that will consolidate all variables, known and unknown. No such meter or gauge exists. The only "all encompassing" evaluation is that provided by the operators while performing the actual missions. Pilots/crew can be viewed as an ultimate measuring device for performance. They experience all of the meaningful variables (known and unknown) and in proper context during the mission.

There are several difficulties in getting and correlating the judgments of the crews which can be compared to the problems of calibrating and reading an instrument. The Cooper-Harper rating scale, which is well known through the aero industry is an approach to this problem for purposes of judging handling qualities. It permits the organizing and collating of many opinions in a semi-quantitative manner. It permits arbitrary

judgment by an individual but provides a standardized descriptive scale to aid in conveying an appreciation of the depth or degree or intensity of his thoughts. It capitalizes upon the experience level of the individual.

Assessment should take into account the reams of measured data and the subjective opinions of the participating crews and should do so according to a process which permits replication and assures credibility.

Consideration in an overall assessment must be given to the hardware/physical properties, which are not responsive to crew judgment, as well as to the performance properties. For example: Survivability is dependent upon having the right information and control capabilities, a performance property. It is also dependent upon having reliable equipment, a physical property.

B. ASSESSMENT. A conclusion about the suitability of a crew system design for this vehicle must include consideration of many factors. These include Mission Performance, Degraded Mode Performance, Efficiency, Effectiveness, Survivability, Reliability, Durability, Maintenance, Producability, Cost Effectiveness, Training, Maintainability.

These factors can be grouped into Performance Assessment and Physical Assessment. In both instances the objective is to use a systematic process for acquiring and merging the judgments of the Evaluation Teams.

1. PERFORMANCE. Performance assessment is accomplished by two groups of individuals, the subject crews and the experimenters. Both are specifically concerned and deeply involved in performance of the system but they have vastly different backgrounds and expertise which can greatly enrich the assessment process. The crew subjects represent a cross section of the operational community who will be using the vehicle. The experimenters have a breadth of experience across many missions and programs.

This assessment is to be accomplished for the Mockup Reviews, the Simulator Test and the Flight Test. Each subject crew member is to provide a personal assessment in each of four areas - MISSION EFFECTIVENESS, WORKLOAD, EMERGENCY, CREW ACCOMMODATION. The Mission area is further divided into five specific portions - TAKEOFF, ENROUTE, REFUELING, CARGO DELIVERY AND LANDING.

The subject crew member's assessment is his final contribution in the routine of the test. Each subject should have the opportunity to "digest" the experience, participate in post experiment debriefings, interviews and discussions as an aide to formulating his individual reactions. Each subject is to present his assessments, no later than two days after his participation, using the Performance Assessment Forms (Appendix E).

The experimenters assessment is to be accomplished only after all subjects have been run and the experiment concluded. It is to reflect their individual judgments based upon their experience and their observations during the experiment. The same forms (Appendix E) are to be used.

2. PHYSICAL. Physical assessment is to be accomplished by a team of specialists to be designated for this task. This team must include one representative for each of the following areas: Logistics, Maintenance, Avionics, Training, Flight Control, Behavioral Science, Life Support, Lighting, Electronic Warfare, Computer Science, Control/Display.

This team will require a substantial amount of time and support in order to render a credible judgment. They must be: briefed on the equipment design and the rationale for the design; provided data on tests performed to determine compliance; and provided the opportunity to examine the equipment.

A preliminary assessment is to be accomplished at the time of the Simulation experiment and an assessment is to be correlated with the Flight Test program and as soon after finalization of equipment as possible.

Each member of the team is to render an assessment, using the Physical Assessment Forms (Appendix F).

C. RATINGS.

1. GENERAL. Any evidence of conflict in crew activities (competition for a control head, incompatible commands or control actions) is a basis for immediate disqualification of the design. This is a condition 1 (RED) rating. (Testing may not progress to levels two or three until the deficiency is corrected.) Any errors in any crewman's performance which could precipitate an accident or failure of the mission is also a condition 1 failure. Any portion of the flight which shows high workload on a crewman while simultaneously permitting a low workload on any other crew member is a condition 2 (AMBER) rating.

2. PERFORMANCE. Judgments have been made by each crew member and by experimenters on the system during various tasks and flight phases. These judgments have been recorded on Performance Assessment Forms (Appendix E) which provide a numerical value for the judgment made. These numerical values provide for the statistical summation of the collective judgments. A mean value of 1, 2, or 3 must be considered a Condition 1 (RED) rating. A mean value of 4, 5, 6, or 7 must be considered a Condition 2 (AMBER) rating. Mean values of 8, 9, or 10 can be considered a Condition 3 (GREEN) rating.

3. PHYSICAL. Judgments have been made by each team member on one or more areas of concern. These judgments have been recorded on Physical Assessment Forms (Appendix F) which provide

a numerical value for the judgment made. These numerical values provide for the statistical examination of the collective judgments. The mean value is the basis for establishing a rating. A mean value of 1, 2, or 3 must be considered a Condition 1 (RED) rating. A mean value of 4, 5, 6, or 7 must be considered a Condition 2 (AMBER) rating. A mean value of 8, 9, or 10 may be considered a Condition 3 (GREEN) rating.

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APPENDIX A

DESIGN SCENARIO

An overview of the design scenario is depicted in Figure A-1, "Ribbon-in-the-Sky".

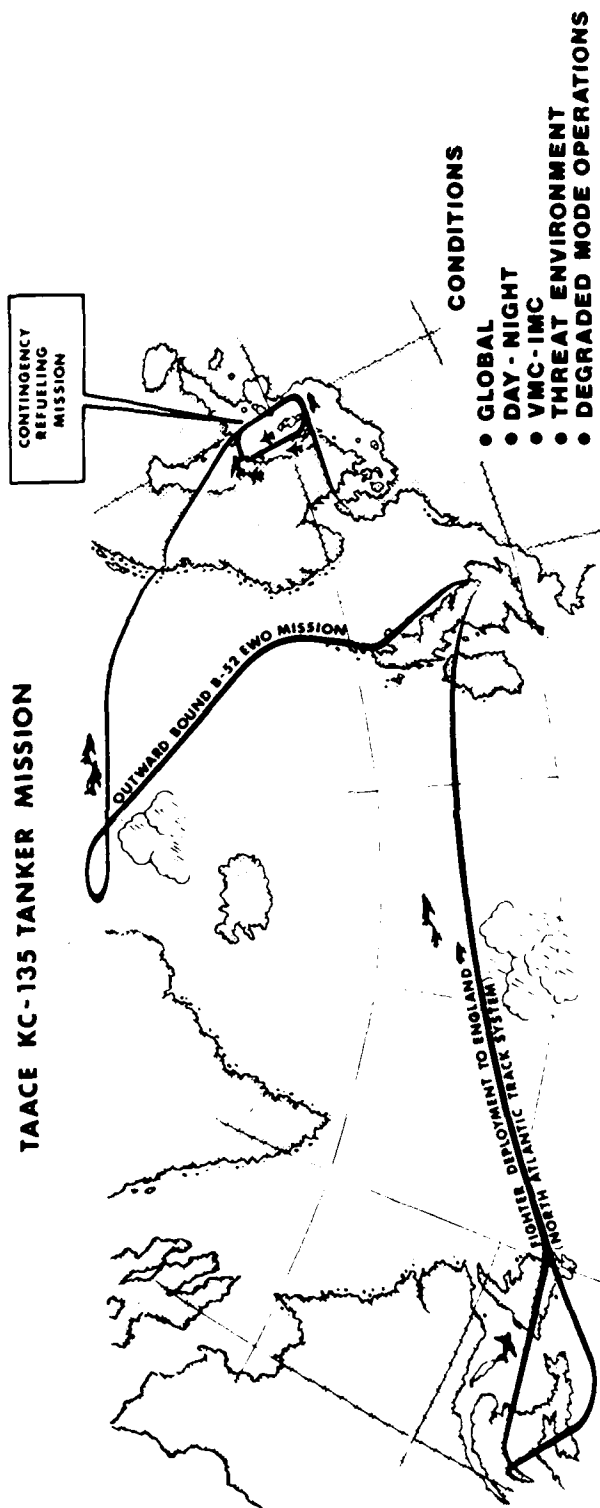


FIGURE A-1
RIBBON-IN-THE-SKY

LORING TO U.K. FIGHTER DEPLOYMENT SUPPORT
(LEG 1)

The 3905 Strategic Aerial Refueling Wing, Loring AFB has been alerted for a Coronet mission to support an increased readiness posture in Europe. A deployment frag is dispatched which directs a five ship tanker force from Loring AFB to support an A-7 unit deployment from McGuire AFB to RAF Wittering. Proposed launch time is 1100Z which is three hours from now. The mission is identified as Coronet Eagle.

Eagle Tanker crews attend the deployment mission briefing which covers crew and aircraft assignment, spares, fuel loads (160,000 pounds), parking spots, navigation routing, procedures for marshalling, departure, formation, join-up, cruise, rendezvous, refueling, and recovery. Status of tanker force is identified as preflighted, but not cocked. Airborne command post (call sign, Head Dancer), Duckbutt¹, weather and alternate recovery procedures are also detailed. An intelligence briefing outlining the European political instability and prognosis of deterioration completes the mission briefing. Eagle crews receive mission kits, obtain a time hack and disburse to complete individual nav planning and pre-departure tasks. The following scenario describes the activities of the crew in the #2 ship (call sign, Esso 2) of the five ship cell (Esso Lead through 5) who are supporting the Coronet Eagle Deployment of 12 A-7 receivers (call sign, Hotel Sierra 1-12). Esso Lead and 2 will deploy to Mildenhall, while the other three tankers return to Loring after offloading fuel to the receivers.

Prior to departing the briefing area, Esso Lead pilot conducts a pre-mission briefing with other cell aircrews covering communications, taxi, takeoff, climb, level off, join-up, formation tactics, offloads, and ARCTs - #1) 1200Z, #2) 1313Z, #3) 1504Z, #4) 1645Z. Weather and emergency procedures are also covered.

The boom operator departs to coordinate for inflight meals while the pilots review and complete flight planning forms, charts and maps. Subsequently, the crew of Esso 2 loads all required equipment on the crew bus and departs base ops at 0935Z. At 0940Z, the Coronet tanker crews arrive at their respective aircraft for preflight and final crew briefings. Taxi out is routine. Esso 2 experiences water failure on takeoff, aborts, returns to the hammerhead to check the system, resets circuit breaker and completes satisfactory check out.

The remainder of the formation departs on schedule and Esso 2 departs 15 minutes behind the leader. A routine IMC departure

¹A C-130 that flies the North Atlantic carrying rescue/survival equipment.

is made with weather at 200' and 1/2 mile. After airborne a change of flight plan is requested to shorten the route so as to rendezvous with the tanker cell over the ARCP at Halifax (YHM) at 1152Z prior to the scheduled rendezvous with the receivers. During level off at FL290 the aileron axis of the autopilot fails and cannot be revived. Due to their late departure, Esso 2 joins the cell in the Esso 5 position and assumes the call sign of Esso 5. During tanker join-up at Halifax, Esso 5 experiences a generator failure which is resolved. During A/R #1, Esso Lead and 5 refueling systems are checked by providing a token offload. After the non-deploying tankers have twice refueled the fighters, they return to Loring and Esso 5 moves into the #2 position. Esso Lead's radar becomes inoperative so Esso 2 assumes responsibility for formation station-keeping and weather avoidance through an extended area where numerous diversions around weather cells are required. At 30° West, halfway across the Atlantic, a third A/R is accomplished except for Hotel Sierra 12. After several unsuccessful attempts to refuel and tow, Hotel Sierra 12, accompanied by Hotel Sierra 11, heads for the closest landfall/airport - Shannon, Ireland with a projected flame out 40 miles short of the airfield. Esso 2 coordinates the problem with Head Dancer and Air Rescue Service and proceeds with the remainder of the Coronet Eagle contingent to the U.K. The fighters top off near Lands End and subsequently break away from the tanker cell to recover at RAF Wittering. The disabled receiver and escort are assisted to Shannon by Head Dancer and Duckbutt. Esso 2 accomplished a minimum weather recovery at RAF Mildenhall at 1820Z.

FIGHTER DEPLOYMENT SUPPORT - LORING TANKER FORCE

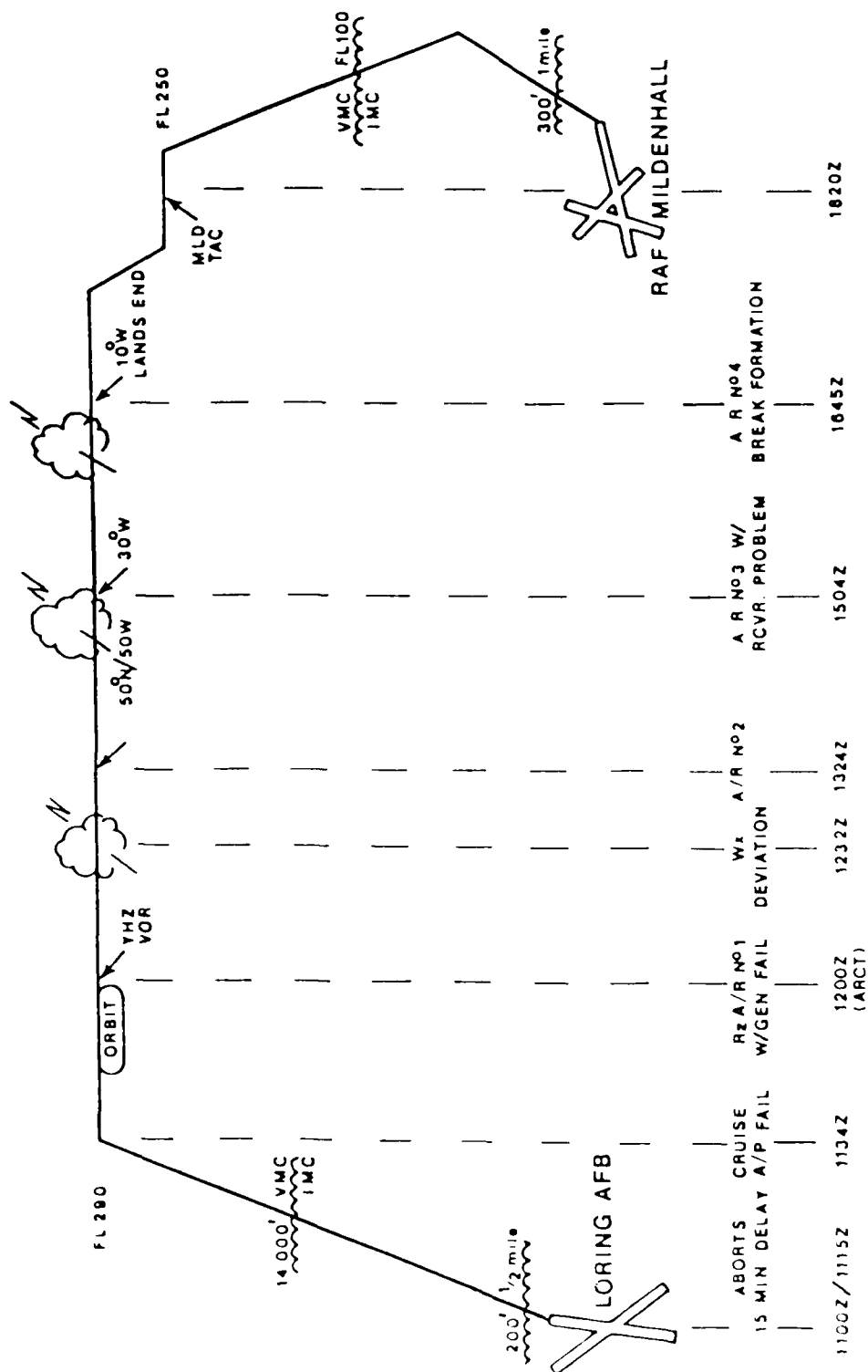


FIGURE A-2
FIGHTER DEPLOYMENT SUPPORT
LORING TANKER FORCE

MILDENHALL RWC MISSION
(LEG 2)

After arrival at RAF Mildenhall, the KC-135 crew has completed their crew rest and are now on alert in the alert facility. Nuclear war appears imminent. The following is a mission scenario for KC-135A, call sign Filip 66. The mission kit shows this aircraft is number 2 in a two ship cell of KC-135s. The takeoff will be from RAF Mildenhall to a rendezvous with two B-52s coming easterly from the United States. The rendezvous point is in a high latitude area at N73° 00' W001° 00'. The ARCP will be 0130Z.

The fuel offload will be 130,000 pounds per each KC-135 with a recovery in northern Norway. The lead KC-135, Filip 61, will be responsible for the navigation and communication enroute. Filip 66 will follow in formation and maintain his relative position (station keeping) from the lead aircraft. The crew will navigate and monitor communications as a backup. The crew has studied the mission and completed the necessary flight planning. The aircraft is cocked. The proposed flight plan and the aircraft's heading and relative position on the alert pad have been stored in the navigation system; however, the INS gyros are not aligned.

As an overview to this portion of the mission scenario, hostilities have broken out between Communist block countries and friendly nations. As a result, the SAC alert force has launched and is proceeding toward target areas. The two ship cell of KC-135s depart RAF Mildenhall at 2200Z, nighttime, with a 3,000 foot ceiling and 7 nautical miles visibility. They climb to FL290 and FL295 respectively, and proceed in IMC conditions by normal navigation and station keeping procedures direct to an overwater, high latitude rendezvous with their two B-52s receivers. Approximately four hundred miles prior to the ARCP, the lead KC-135 experiences an uncontrollable engine fire. That aircraft leaves the formation and sets course toward an emergency recovery base, while Filip 66 proceeds. When approaching the ARCP, several severe thunderstorms with tops estimated at above FL400 are detected in the planned refueling track by Filip 66 and the two B-52 receivers, Bozo 21 and Bozo 24. A new refueling track clear of the thunderstorms is plotted and coordinated between aircraft. Authentications are completed and a diversion is made to the new refueling track. A point parallel rendezvous is completed. Filip 66 refuels both Bozo 21 and 24, since the other tanker was not available. Filip 66, with only emergency fuel, recovers at the nearest airfield, Bodo, Norway. Ground navigation aids have been shut down or jammed so an airborne radar approach (ARA) is made with only enough fuel for one approach. The weather at Bodo is a 400 foot ceiling and 1 nautical mile visibility in nighttime conditions. This leg of the mission is further complicated by a stabilizer trim failure on departure, the tankers rendezvous beacon being inoperative, smoke and fumes from the air conditioning system being detected during the aerial refueling of the B-52s and two engines flaming out from fuel starvation on final approach prior to a successful recovery at Bodo, Norway.

MILDENHALL EWO MISSION

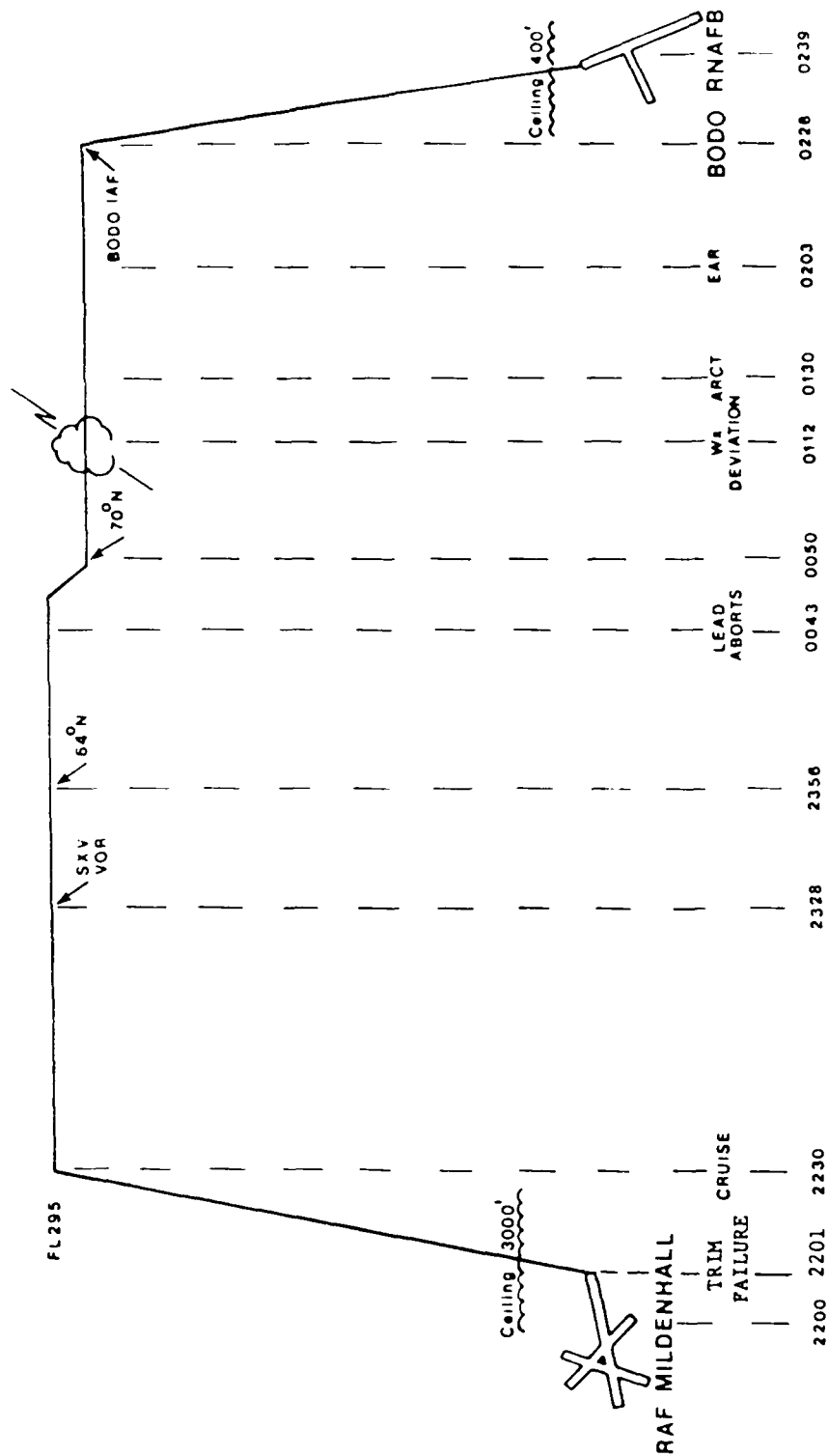


FIGURE A-3
MILDENHALL EWO MISSION

BODO CONTINGENCY MISSION
(LEG 3)

The KC-135 has been towed off the taxiway at Bodo, maintenance discrepancies have been corrected, and it has been refueled with 120,000 pounds of fuel. A thru-flight inspection has been performed by the crew chief. The pilots proceeded to operations where they contacted their operation center through NATO land line communications. They reported Filip 61's emergency, his unknown disposition and the amount of fuel offloaded to each of Bozo 21 and 24. They were directed by their operation center to relaunch as Lead in a two ship cell with Taco 33, another KC-135 which recovered at Bodo. Taco 33 has an inoperative navigation management system, but an operable radar. They are to proceed to an anchor point over the Baltic Sea at N58°40", E19°40" to refuel multiple flights of fighters striking targets in Western Eurasia. The air refueling control time (ARCT) is 0845Z. The tankers' altitudes in the anchor will be FL290 and FL300. The receivers will be authenticated and vectored by GCI Control. Filip 66 and Taco 33 are to remain in the refueling track until they have only enough fuel remaining to safely recover at Aalborg Royal Danish Air Force Base, Denmark.

The crew obtains an intelligence briefing from NATO Ops. NATO is involved in a limited hostilities with the Soviet block nations. Aircraft are operating on tactical clearances without air traffic control clearances. Some control towers and military radars are operating. Most navigation aids are operational and jamming and interference is taking place on all communication radios. Nuclear detonations are possible. Crew are advised to wear gold goggles. Enemy fighter aircraft have been reported infringing upon free airspace from both ground bases and aircraft carriers.

Mission and crew briefings are completed. The crew inserts the proposed flight plan into the nav management system. The INS systems are aligned prior to taxiing. As Lead, Filip 66 makes a two ship, day, IMC departure with ceiling at 400 feet and visibility at 1 mile. The aircraft climb to FL290 and FL295 respectively, and proceed to the anchor point, where the pattern is established prior to the control time. Taco 33 climbs to FL300. Enroute to the ARCT, an electrical system malfunction occurs and subsequently the pilot's nav management system control/display unit (CDU) becomes inoperative, requiring all further navigation interface to be conducted through the copilot's CDU. GCI assistance is not available until after the aircraft are in the anchor.

GCI vectors numerous F-15, F-16, A-7, and F-4 aircraft, formations and single ships, in for refueling from both tankers. Fighters are both inbound to and outbound from target areas. Some are required to hold out while others are on the tanker.

Some are extremely low on fuel, requiring coordination of priority treatment. In one case Filip 66 is required to cut short the anchor and proceed toward a point away from the anchor pattern closer to an emergency fuel fighter. The pattern is also complicated by several weather cells which must be circumnavigated along one side of the anchor.

After approximately 1 1/2 hours in the pattern, enemy fighters attack the refueling formation. A nuclear device is detonated and Filip 66 is subject to an electro-magnetic pulse (EMP). The loss of all non-hardened avionics systems ensues, leaving Filip 66 without communications and with only limited flight instruments and navigational capability. Most electrically operated controls and indicators are inoperative. The boom operator, in the boom pod without his goggles, is blinded by the flash. Filip 66, unable to see or communicate with Taco 33, turns southwestward and descends to FL140 to maintain terrain clearance. He continues to dead reckon to a position believed to be over the North Sea just west of Denmark and makes a slow spiraling descent to VMC conditions over the water. He then turns northeast and proceeds until landfall on the northwest coast of Denmark. Using dead reckoning he proceeds visually to Aalborg Royal Danish Air Force Base. A visual approach is made to Aalborg with the ceiling at 1,100 feet and the visibility at 3 mlles. The landing gear and wing flaps are extended manually and a successful landing concludes this portion of the mission.

BODO CONTINGENCY MISSION

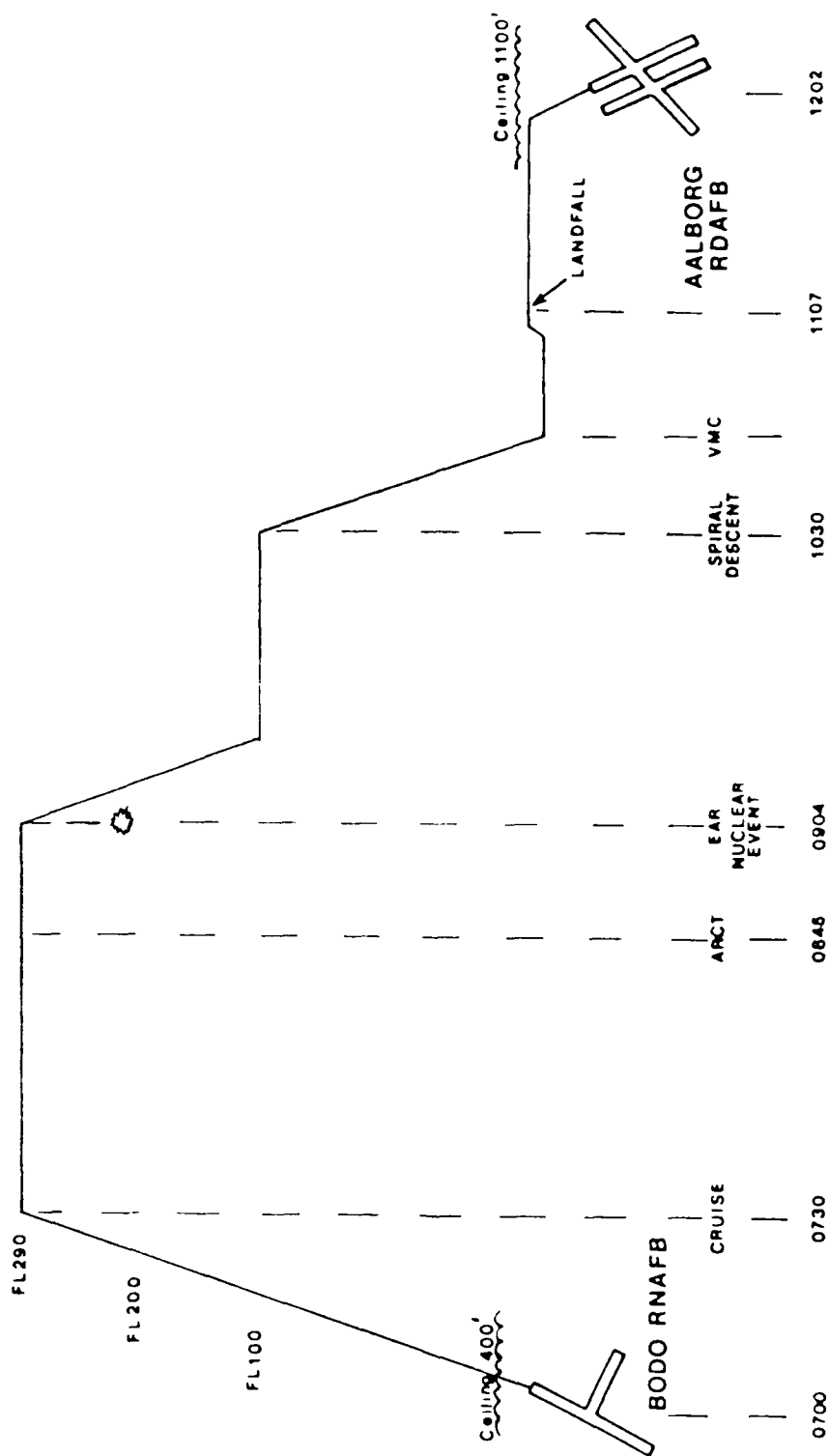


FIGURE A-4

BODO CONTINGENCY MISSION

APPENDIX B

QUESTIONNAIRE FOR CREW REACTION

CREW REACTION

WORKLOAD

Crew Position _____

Crew Number _____

Mission Segment:

Deployment/EWO/Contingency

AP 1st Half/AP 1st Half

BON/COF/POF

N/U/UPS

For the previous mission segment, mark on the scale the position which best reflects your judgment of the workload for you for each of the following topics.

	High	Medium	None
1. TAKE OFF	0	5	10
2. DEPARTURE	0	5	10
3. CLIMB	0	5	10
4. CRUISE	0	5	10
5. AERIAL REFUELING	0	5	10
6. DESCENT	0	5	10
7. APPROACH AND LANDING	0	5	10
8. NAVIGATION	0	5	10
9. COMMUNICATION	0	5	10
10. PILOTING	0	5	10
11. PAPERWORK	0	5	10

APPENDIX C

EXPERIMENTERS' SCRIPT

LORING TO MILDENHALL

Esso 2 crew has completed the exterior inspection. The Interior Inspection checklist is in progress. Esso lead is calling for Esso flight to check in on UHF when ready to start engines. You have not received launch message. Time is 1015Z or start (1030Z) minus 15 minutes and takeoff (1100Z) minus 45 minutes. Experimenter: Remind crew that all crew tasks and nav legs are to be completed in real time unless instructed otherwise.

Elapsed Time Hr:Min			
00:00	Esso flight, Esso 01, check in on Ch. 9 when ready to start. (311.0) Roger, Esso Flight.	(Experimenter: after item 25 on interior checklist is completed, start script.)	3, 4, 5, Spare.
00:02	Yoke Control, Esso flight, ready to copy launch message.	For Esso flight, this is Yoke Control. Takeoff on your scheduled timing. Time (present <u>Z</u> time)/(today's date). Authenticate Alpha Kilo Alpha (wait for authenticate response). For	
00:03	Roger, Yoke, Esso - Tango Echo Delta.		

Elapsed
Time
Hr:Min

2

<p>00:04 Roger, Yoke Control. Esso copies.</p> <p>00:06 Esso flight, 01, check in on ground control. Loring Ground, Esso flight request altimeter and fire guard for engine start time of 1030Z.</p>	<p>Esso flight, message follows: (In phonetics) Lima, Oscar, Romeo, (pause) Metro, Lima, Delta, (pause) India, Foxtrot, Romeo, (pause) Sierra, Uniform, Papa, (pause) Echo, Uniform, Romeo, (pause) Papa, Golf, Three, Five, Two, (pause). Runway 01, wind 360/10, temperature 43, pressure altitude 740'. I say again, For Esso flight, message follows: (repeat message).</p> <p>Item 31. (Wheel well) doors - clear - CP). Esso flight, Loring Ground,</p>	<p>3, 4, 5, Spare.</p> <p>3, 4, 5, Spare.</p> <p>Pilot-Ground. Wheel well doors are clear.</p>
--	---	--

Elapsed
Time
Hr:Min

3

	Roger Ground, Esso, that's affirmative.	altimeter 2990, fire coverage in effect. Confirm stubs are 20-25. Item 41. (Fuel dump activator-checked - CP).	Pilot-Ground. Boom fully retracted.
00:08	Esso flight, come up 124.7 for radio check and check in. Roger, Esso flight. Let's go back Ground Control.	(Dump switch - Fuel dump).	3, 4, 5, Spare. Pilot-Ground. Poppet valve open. Dump actuator reset. Poppet valve closed.
00:09	Yoke Control, Esso 01. Roger, Yoke Control Esso flight will start on time. My nav system is a little squirrely so we'll take spare out to the hammerhead. Esso Spare, did you copy?	Go ahead, Esso, this is Yoke. Roger, Esso 01. Yoke Control concurs.	Spare copies.

Elapsed
Time
Hr:Min

4

00:10 (1030Z) Loring Ground, Esso flight starting engines.	(Experimenter: We move forward to start engine time.) (Ready to start engines.) Roger, Esso, Loring Ground. (#1 switch activated.) (#1 throttle to idle.) (REPEAT FOR ENGINES 2, 3, & 4.) (Disconnect external power and remove chocks.)	(Ground crew replies.) Chocks in place, engines clear, fire guard standing by. (Ground crew reports by observing crew actions in TV monitor.) #1 turning. Good start on #1. (Ground crew replies.) Chocks, pitot covers, ground wires, and external power removed; upper and lower rotating beacons on and rotating; disconnecting interphone cord and coming (or not coming) ahead.
--	--	---

Elapsed
Time
Hr:Min

5

Esso flight, check in when ready
to taxi.

3, 4, 5, Spare.

00:14

Esso 3 is ready to taxi; 4 is ready;
5 is ready; Spare is ready.

00:15

Loring Ground, this is Esso 01,
request clearance to taxi.

Roger, Esso 01, you are cleared
to taxi runway 01. Winds are
360 at 10. Altimeter 2990. Your
clearance is on request.

3, 4, 5, Spare.

00:16

Esso, this is Loring Ground, I
have your ATC clearance.

Roger, Ground, Esso 01 go ahead.

Roger, Esso, you are cleared as
filed to maintain FL290. Cross
Houlton at or below FL200.

Elapsed
Time
Hr:Min

00:17	Roger, ATC clears Esso as filed, FL290, cross Houlton at or below FL200.	Esso flight, readback is correct. Contact Loring Tower when ready for takeoff.	3, 4, 5, Spare.
00:18	Esso 01, Yoke Control, how is your nav system? Roger Yoke, Esso 01, nav system checks OK.	(Experimenter: We now move for- ward to original takeoff time minus 5, 1055Z.)	
00:19	Esso flight, let's go Tower and check in.		3, 4, 5.

Elapsed
Time
Hr:Min

7

00:20 Loring Tower, Esso flight, ready
for takeoff.

(Response) Roger, Esso flight,
Loring Tower, cleared into posi-
tion and hold runway 01. After
takeoff climb straight ahead to
4,000 feet then turn right to 090
and continue climb to assigned
altitude. Contact Loring Depar-
ture Control 124.7 when airborne.
Squawk 2200.

00:21 Roger, Loring Tower 01 understands
position and hold. Squawk 2200.

3 copies, 4 copies, 5 copies.

Esso flight, Loring Tower, that
is correct. You are cleared for
takeoff. Winds 360 at 10 knots.

00:22 Esso 01 rolling.

(1100Z)

Elapsed
Time
Hr:Min

00:24	(Experimenter: Fail water on both inboard engines at 100 knots. If pilots overlook the failure, call "abort".)
00:25	Esso 2, Tower, observing your abort. Do you need assistance?
00:26	Roger, Esso 2, Loring Tower. You are cleared for taxi back. When clear of active, contact Ground Control.
00:27	Esso 2, 01 on 9, what's your status?
00:28	Esso 2, Esso 01, you are now Esso 5. We'll see you at Halifax and talk on A/R frequency. Break -

Elapsed
Time
Hr:Min

9

Esso flight, change your call signs, now. Compress one number and acknowledge.
Yoke Control, Esso, please coordinate these changes with ATC and base ops.
Esso Spare, Yoke Control, maintain position on hammerhead. If 5 krumps, get your release from ATC and join Esso at Halifax AR track.

Yoke Control, wilco, Esso.

00:29

Spare copies.

Esso 2, Ground Control, clear to taxi back. Do you want me to hold your flight plan open?

00:30

Esso 2, Ground, are you changing call signs?

2, 3, 4.

Elapsed
Time
Hr:Min

10

00:31

(Response) Roger, Esso 5, Loring Ground you are cleared to continue taxi runway 01. Winds are 350-360 at 10. Altimeter is 2989.

Esso 5, Yoke Control, confirm you are preparing to launch.
(Response) Roger, Esso 5, Yoke copies. Be advised your call sign and clearance change has been filed with Base Ops.

00:32

Esso 5, Loring Ground, I have your ATC clearance.

(Response) Roger, Esso 5, ATC clears Esso 5 to destination via Houlton, St. John, flight plan route to maintain FL250.

Cross Houlton at or below FL200.

Roger, Esso 5, your readback is correct/incorrect. Contact Metro

(If requested):

Direct to Grand Lake Int. HL578A, Halifax, maintain FL250.

Elapsed
Time
Hr:Min

11

00:33

for message. Contact Tower when finished with Metro.

Roger, Esso, Loring Metro, I have an update on your enroute weather. Be advised there is scattered to broken cumulus activity developing along your route which is now forecast to top out occasionally above 40,000. This weather could affect your flight from Halifax to 20 West, over. (Pause for response)
Esso, Metro, will you pass pireps back every hour or so covering enroute conditions?

00:34

(Ch 9) Esso 5, this is Esso 01.
(Response) Roger, Esso 5, give me a call when you get airborne.

Elapsed
Time
Hr:Min

12

00:35

(Response) Roger, Esso 5, Loring Tower, you are cleared into position and hold runway 01. Esso 5, I have an amendment to your clearance.

(Response) Roger, Esso 5, after takeoff, climb straight ahead to 4,000 feet then turn right to 090 and continue climb to assigned altitude. Contact Loring departure control 124.7 when airborne. Squawk 2200.

00:36

(1115Z)

(Response) Roger, Esso 5, read-back correct/incorrect. Change to departure control 124.7. Cleared for takeoff.

(Experimenter: Time is 1115Z when airborne. Adjust time as required.)

Elapsed
Time
Hr:Min

13

00:38

(Response) Roger, Esso 5, this is Loring departure control say altitude passing.

(Experimenter: 4000')

(Response) Roger, Esso 5, Esso 01. I have you airborne. (Or asked by 01, "What time airborne" [1115Z])

00:39

Esso 5 Loring departure, radar contact.

00:40

(Response) Roger, Esso 5, I have you passing 10,000. Maintain present heading. Contact Moncton Centre on 227.2, squawk 2422.

(Response) Roger, Esso 5, Moncton Centre. Squawk ident.

(Pause) Esso 5, radar contact. Say intentions.

Elapsed
Time
Hrs:Min

14

<p>00:41</p>	<p>(Response) Roger, Esso 5, direct routing to Halifax is available. Maintain present heading. Standby for clearance. Esso 5, Moncton Centre, you are cleared to the Halifax VOR via present position direct to Grand Lake intersection, HL578A to maintain FL250. Call passing FL200 and Grand Lake, over.</p>	<p>(Experimenter: Prompt the crew if direct clearance is not requested. If it has been requested earlier, clearance delivery may be delayed until this time.)</p> <p>(Experimenter: Grand Lake is HUL 106/68 or N460820 W0661240.)</p>
<p>00:43</p>	<p>Esso flight, Yoke Control, be advised Head Dancer is airborne.</p>	
<p>00:46</p>	<p>(Response) Roger, Esso 5, that is correct. Did you call out of FL200, Esso 5? (Pause) Roger, Esso 5, Moncton copies.</p>	

Elapsed
Time
Hr:Min

15

00:47	Esso 5, this is Esso 01. (Response) Roger, Esso 5, say your position and Halifax ETA. Also, say your routing. (Response) Roger, Esso 5.
00:49	Esso 5, 01, be advised you will run your own Rz, start your count- down at Parrsboro.
00:50	Esso 5, contact Moncton Centre on 124.4. Squawk 3030. (Response) Roger Esso 5, ident. (Pause) Radar contact.
00:51	Esso 5, 01, say your ETA and distance to Halifax. (Response) Roger, Esso 5.

(Experimenter: Check use of wpt
data page.)

Excerpt
Time
1964

16

00:53

Esso 5, 01, say your radial and
distance from Fredericton.
(Response) Roger, 5.

00:54

Grand
Lake

Esso 5, Moncton Centre. Be ad-
vised I have you at Grand Lake at
this time. How does that check
with your equipment?

(Response) Roger, Esso 5, under-
stand. Change now to Moncton
Centre on 132.1.

00:55

Esso 5, Esso 01, give me a call
when you have beacon contact.

(Response) Roger, Esso 5, Moncton.
Squawk 3732. Ident.

(Response) Roger, Esso 5, Moncton,
my radar is down. Are you level
FL250?

(Experimenter: Ask pilot to use
nav aids data and PPSN.)

Elapsed
Time
mm:Min

17

00:57	<p>(Response) Roger, Esso 5, call passing Parc intersection.</p> <p>Esso 5, Moncton, I have a traffic conflict at Sussex. Climb now to FL270. Report passing FL260, over.</p> <p>(Response) Roger, Esso 5, through 260.</p>	<p>(Experimenter: Monitor hold entry on nav mgt.)</p>
00:59	<p>Esso 5, Moncton Centre, plan to hold at Sussex for traffic. Advise when entering holding.</p>	
01:01 (Sussex)	<p>(Response) Roger Esso 5, Moncton, hold for one standard orbit at Sussex and then proceed to Halifax. Say estimate to Parrsboro.</p>	

Elapsed
Time
hr:min

10

01:03	Esso 5, Yore, say radial/distance from home plate for Head Dancer. (Response) Roger 5, copy.	Esso 5, Moncton, you are cleared on course to Halifax.	(Experimenter: Check use of wpt data page entry on PPSN page.)
01:05	Esso 5, 01, say your distance from Halifax. (Response) Roger, Esso 5.		
01:06 (1145Z)	Esso 5, Esso 01, I am entering orbit at ARCP Halifax. Are you painting my beacon? (Response) Roger, Esso 5. Are you picking up my TACAN? My TACAN is on Y Channel 20. Give me DME and bearing.	Esso 5, Moncton call passing Parrsboro.	(Experimenter: Esso 5 should paint 01 beacon. Deck should start beacon at this time.)
01:09 (Parrs- boro	Esso 5, 01, give me a beacon check every ten miles.	(Response) Roger, Esso 5, Moncton. I have you by Parrsboro. Clear to FL310.	

Elapsed
Time
HH:MM

19

01:11

Hotel Sierra, this is Esso 01.

Sierra, Esso has a new line up.

First, I want a boom check on
Esso 01 and 5, then take AR 1
and AR 2 from the middle three
tankers, call signs Esso 2, 3,
and 4. Be advised Esso 5 got
off late and will join us at
the ARCP.

(Experimenter: Esso 5 crew
should call every 10 miles, until
tally ho with Esso 01.)

Esso 5, Moncton, change now to
368.5.

Go ahead, Esso, Sierra here.

Roger, Esso, Sierra copies.

Esso 01, Sierra Lead will check your
boom as briefed. Sierra 9 will
check Esso 5 boom when he joins up,
over.

Excluded
Time
Hr:Min

20

01:12

Copy, Sierra, Esso copies. Are

you ready to copy Am info?

Roger,

Am Rendezvous Altitude - FL270

Altitude Setting - 2972

Offload - Top Off

End of 1st/2nd/3rd Heading - 095

Drift Inbound - 1.00 ft

Weather in A/P Area/Recovery Base

Area is Clear and Clear at Gander

(Information To Be Confirmed)

Hot Armament Check

ETA To Rendezvous Point (1210Z)

Rendezvous Altitude (FL270)

Inbound Track (079)

TAS for Rendezvous (500)

Turn Range 21NM, OFFSET 30°

Clearance Requirements (As Briefed)

Sierra, Roger, go ahead Esso.

(Esso 5 should copy.)

Elapsed
Time
hr:min

21

		<p>Moncton, Hotel Sierra 80 miles from Halifax. Request descent from FL370 for 270.</p>
	<p>Hotel Sierra, Moncton has you at 80 miles. Cleared to FL270. Esso 5, Moncton ident. (Pause) Esso 5, still no radar.</p>	
	<p>Esso 5, Moncton, you are cleared to enter A/T track at Halifax, left turn, 083 inbound, maintain FL310 until visual with Esso flight.</p>	<p>Hotel Sierra copies. Hotel Sierra is level at 270.</p>
	<p>Hotel Sierra, Moncton, call level 270. Moncton, Roger.</p>	<p>Hotel Sierra, Roger 60.</p>
<p>01:13</p>	<p>Esso 01 copies. Break. Hotel Sierra I have your beacon now at 70 miles. Break. Esso 5, Esso 01 is inbound to R2 with Sierra. Continue your R2 with me. Call Halifax at FL310.</p>	
<p>01:14</p>	<p>Hotel Sierra, I have you at 60 miles.</p>	

Elapsed
Time
Hr:Min

22

	Hotel Sierra, Esso 01, hold down for DF.		Roger, Esso, Hotel Sierra transmitting for DF. (Pause)
01:15	Hotel Sierra you're at 50 miles. Roger, Hotel Sierra, Esso, I have you 14° south of my track at 40 miles.	(Response) Roger Esso 5, Moncton has you by Halifax entering AR track. Call when joined up.	Hotel Sierra copies.
01:16	(Response) Roger, Esso 5, understand you have a generator failure. Let me know when you have it squared away.	(Esso 5 should call in over ARCP. Experimenter: #1 generator failure. After the crew moves the generator control switch closed and checks the voltage-- it reads normal. The #1 breaker circuit light is also on. When the crew	Roger, Hotel Sierra copies at 40 miles. Head Dancer copies.

Elapsed
Time
Hr:Min

23

		<p>resets the breaker circuit switch to "close", the #1 breaker circuit open light remains on. When the generator control switch is tripped, the #1 bus is carried by the remaining generator.)</p> <p>Moncton copies, Hotel Sierra.</p>	<p>Hotel Sierra copies and level at 270.</p> <p>Hotel Sierra copies 25 miles.</p> <p>Hotel Sierra copies 24 miles.</p> <p>Hotel Sierra copies 23 miles.</p> <p>Hotel Sierra copies 22 miles.</p>
			<p>Hotel Sierra 30 miles.</p> <p>Hotel Sierra 25 miles.</p> <p>Hotel Sierra 24 miles.</p> <p>Hotel Sierra 23 miles.</p> <p>Hotel Sierra 22 miles.</p>
01:17	Hotel Sierra 21, Esso 01 starting turn to A/R heading.		<p>Hotel Sierra copies 21 miles.</p>
01:19	Esso 5 confirm you are in trail. Esso 01 is halfway through turn.	<p>(Experimenter: Esso 5 should be calling every 10 miles to Esso 01.)</p>	<p>Esso flight. Hotel Sierra has a tally ho at 12 miles.</p>

Elapsed
Time
Hr:Min

24

01:20	Roger, Esso 01 copies tally. (Response) Roger, Esso 5, 01 has you starting your turn and has tally ho. Esso flight echelon right. Go A/R frequency and check in.	Moncton Control, Hotel Sierra is departing FL270 for 290, joining Esso flight.
	Roger, Hotel Sierra. Moncton copies. Contact Esso on A/R frequency.	2, 3, 4, (5).
01:22	Roger, Esso 5, in position.	Hotel Sierra, roger. Sierra flight go 326.6. Hotel Sierra Lead on 326.6, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. Esso, Sierra Lead 3 miles - push it up Esso.
	Roger, Sierra, Esso copies. Esso pushing it up to 305 indicated.	

Elapsed
Time
Hr:Min

25

01:22 (ARCT)	(Experimenter: Update crew with time of 1200Z, ARCT.)	Sierra Lead, boom 01 how copy? Sierra Lead reads boom 01, 5 by. Roger, Sierra Lead cleared to pre-contact.
(1200Z) A/R #1	Moncton, Esso has receivers. Roger, Esso, Moncton. Cleared to conduct A/R.	Sierra Lead, Roger, pre-contact. (Sierra 9, boom 5, how copy?) Sierra 9 reads boom 5, 5 by. (Roger, Sierra 9, cleared to pre-contact.) Sierra 9, Roger, pre-contact.
01:23	Roger, Moncton, Esso is departing Halifax at this time. Moncton, Esso requests VHF frequency.	Sierra Lead, cleared to contact. (Sierra 9, cleared to contact.) Sierra Lead contact/boom 01 contact.

Elapsed
Time
Hr:Min

26

Esso go 132.2 and check in.		Sierra 9 contact (boom 5 contact).
Moncton, Esso on your frequency 132.2.	Roger, Esso, Moncton copies.	2, 3, 4, (5).
Roger, Moncton, Sydney (ETE 19 minutes). 1222Z	Esso, Moncton, say your Sydney ETA.	
Sierra flight, Esso 01, we are passing Halifax. Estimate Sydney 1227Z.	Moncton copies.	Sierra Lead disconnect now. You have your onload of 1,000 pounds. Sierra Lead disconnect. (Sierra 9 disconnect now. You have your 1,000 pounds onload.) Sierra 9 disconnect

01:24

Elapsed

Time

hr:min

27

01:25

Sierra Lead clear of boom.

Sierra Lead copies.

(Sierra 9 clear of boom.)

Sierra 9 copies.

01:30 - 01:35

Experienced Inform Esso 5 crew that we are moving forward to 50 North/33 West. AP #1 and #2 have been completed. Hotel Sierra 12 had a temporary A/R hookup malfunction but appears OK now. Esso 2, 3, and 4 have returned to Loring as briefed. Several minor weather diversions have been necessary and the weather is deteriorating. Head Dancer is 10 miles in trail at F-312. Thirty minutes prior to A/R call has been acknowledged. Preparation for contact checklist has not begun. Esso 5 crew will be given time to reorient themselves to their new location before we resume flight. No change in call sign. Esso 01 has been in contact with Mac Dill Airways 13244 HF. The time will be 1451Z. Flight level is 295 and airspeed is 305 IAS on 090 flight plan course. Fuel status is 125K.

Elapsed
Time
Hr:Min

28

01:35	Esso 01, Sierra Lead, are you painting weather 12 o'clock, 40 miles?	
01:36	Standby one Sierra Lead. Sierra Lead, Esso 01 has no paint. Esso 5 how does it look to you?	(Experimenter: Crew should see heavy weather cells 12 o'clock, 33 miles.) (5 passes WX to Lead.)
01:39	Roger, Esso 5, 01 understand heavy cells 12 o'clock, 33 miles. Can you give me a vector heading while I see what I can do to get this radar back up?	
01:40	(Response) Roger, Esso 01 copies heading.	(5 gives heading for WX avoidance.)

Elapsed
Time
Hr:Min

29

Esso 5, 01, my radar is out. Are
your systems working well enough
to assume cell command?

01:41 Roger 5, Esso 01. Hotel Sierra,
be advised Esso 5 will now assume
command of this flight. Esso 01
will maintain cell position.

(5 confirms good systems.)

Hotel Sierra copies.
(Esso 5 copies.)

(Experimenter: It is assumed that
Esso 5 will make position reports
unless 01 is requested to do so.
Tell the crew to perform SKE, wx
avoidance, navigation and other
responsibilities of command.
Someone must make 50/30 position
report to MacDill.)

Elapsed
Time
Hr:Min

30

Esso flight this is MacDill Airways.
Can you give me a weather report?

(Esso 01 responds to heading
changes from Esso 5 or prompts him
for heading information.)

01:45 Esso 5, 01, confirm line up is:
Sierra 1-6 on Esso 01, Sierra
7-12 on Esso 5.)

01:48 Esso 5, 01 is ready for A/R 3.
Request clearance for 01 and
Sierra 1-6 to go A/R backup on
326.0.

(Response) Roger, Esso 5. Sierra
1-6 1-6's go 326.0 and check in.

(Sierra 7, Boom 5, cleared to pre-
contact.)

Sierra 7, Boom 5.

Elapsed
Time
Hr:min

31

01:50 1506Z ARCP #3 50/30	(Response) Roger, Roger, Esso flight MacDill copies 50/30 posi- tion. Call Croughton this fre- quency. (Croughton no response 13244.)	(Boom 5 clears Sierra 7 to contact.) Sierra 7, Roger.
01:51	(Croughton responds 8933.) (Response) Roger, Esso, Croughton Airways copies 50 North/30 West location. Call 20 West.	Sierra 7 contact (boom 5 calls contact.)
01:53		(Esso 5 clears Sierra 7 to disconnect.) Sierra 7, disconnect.
01:54		(Sierra 7 clear of boom, 5100 pounds.) Sierra 7 copies 5100.

Elapsed
Time
Hr:Min

32

01:55	(Esso 5 clears Sierra 9 for contact.) Sierra 9, Roger.
01:57	Sierra 9 contact (boom 5 calls contact.)
01:58	(Boom 5 clear Sierra 9 to disconnect.) Sierra 9 disconnect.
01:59	(Boom 5 gives Sierra 9 boom clearance.) (5100 pounds) Sierra 9 copies 5100.
02:00	(Esso 5 clears Sierra 11 to contact.) Sierra 11, Roger.
02:00	Sierra 11 contact (Boom 5 calls contact.)

Elapsed
Time
Hr:Min

33

02:03

(Boom 5 call disconnect for Sierra 11.)
Sierra 11 disconnect.

02:04

(Boom 5 gives Sierra 11 boom clearance.
5500 pounds)
Sierra 11 copies 5500.

02:05

(Boom 5 clears Sierra 8 to contact.)
Sierra 8, Roger.

02:07

Sierra 8 contact/(Boom 5 calls
contact).

02:09

(Boom 5 calls Sierra 8 disconnect.)
Sierra 8 disconnect.

02:10

(Boom 5 gives Sierra 8 boom clearance.
5700 pounds)
Sierra 8 copies 5700.

Elapsed
Time
mm:ss

34

02:11

(Boom 5 clears Sierra 10 to contact.)
Sierra 10, Roger.

02:13

Sierra 10, contact/(Boom 5 calls
contact).

02:14

(Boom 5 calls Sierra 10 disconnect.)
Sierra 10 disconnect.

02:15

(Boom 5 gives Sierra 10 boom clear-
ance. 5900 pounds)
Sierra 10 copies 5900.

02:16

(Boom 5 clears Sierra 12 to contact.)
Sierra 12, Roger.

02:18

Sierra 12 no contact.

A/R

(Boom 5 suggest recycling A/R system
and try again. No success. Boom 5,

Problem

(Inside experimenter may suggest
the crew to go by Dash one, i.e.

Elapsed
Time
on Way

35

Esso 5, Esso 01 back on your frequency. Do you want me to advise Head Dancer and Duckbutt of A/R problem?	(1) recycle A/R system and additional contacts (no success); (2) manual boom override (no success); (3) emergency boom latch (excess fuel spill - no success); (4) attempt tow hookup (no success - receiver manual latch inoperative).	consider options listed in center column.)
Sierra Lead to flight, check in.		2, 3, 4, 5, and 6.
		Esso 5, Sierra Lead, say pigeons to nearest airfield and nearest landmass.
		Roger, Esso, Head Dancer copies problem. Say intentions of receiver.
		Roger, Esso, Head Dancer, would you like for me to coordinate with Duckbutt, Croughton and Shannon.
		Roger, wilco. Head Dancer will call you back, Esso.

02:20
EAR #3
(1536Z)

Elapsed
Time
Hr:Min

36

02:22

Sierra 12, Sierra Lead say your fuel state.

Roger Lead, Sierra 12 has 5500 pounds.

Roger 12, set us maximum range speed of 350 TAS and pick up course for Shannon. Sierra 11, go with 12 on his wing. 12, it looks like you will get over Shannon with 800 pounds and on the ground with zilch. Declare an emergency and get a cruise descent and a straight-in approach. Break Esso 5, do you have access to Shannon weather? Repeat pigeons to Shannon for Sierra.

(Inside experimenter may remind crew of WX information through Croughton.)
(Response)

Roger, Esso 5, Croughton standby.

Esso 5, Croughton, Shannon weather 500 overcast, 1 mile. Forecast no change. Cork and

02:24

Elapsed
Time
H:MM:SS

37

Lands End are carrying slightly
lower. Be advised, I have issued
clearance to Sierra 12 through
Head Dancer. Do you want a repeat?

02:26

(Esso 5 passes WX to Sierra.)

Roger, Esso 5, Sierra Lead copies

weather. Sierra 12 did you copy

Shannon WX?

Sierra 12 copies WX.

Sierra 12, Head Dancer, if you copy,
come up on 243.0.

Sierra 11 and 12, Lead, approximately
740 true to Shannon and go now with

Head Dancer 243.0.

11 copies, 12 copies.

Head Dancer, Sierra 12 on 243.0 and
reading you 4 by.

Roger, Sierra 12, Head Dancer is in
contact with Duckbutt at 16 west.

U.S. 11

243.3.

Esso 5, Head Dancer, I will fly cap
for Sierra 12 and try to rendezvous
with Duckbutt.

XX

Experimentor: Flight proceeds past 50N/20W at 1556Z, completes routine A/R #4 between 50/10 and 50/08 and is working London Control on 122.6 MHz. Cell has terminated and fighters are enroute to RAF Wittering. You are over Brize Norton. You have not contacted Metro for MLD wx or MLD Command Post (Dingbat). You are cleared as filed F2090. Course is 071°, with 3 to IAS. Fuel status 31K. Time is 1735Z as flight resumes. Crew may have time (5 min) to reorient.

Elapsed
Time
Hr:Min

02:35
1735Z

(Response)

Roger Esso, this is (Brize) metro, pre-sent Mildenhall weather is 300 overcast, 1/2 mile in light drizzle and fog. Winds are light and variable. Altimeter 2989. Mildenhall forecasts a slight improvement during the next hour. Over.

Esso 01 copies wx.

02:36

(Experimenter: Flight passes by Brize Norton at 1735Z.)

Esso, London, I have you by Brize Norton.

02:37

Esso flight, London Military, you are cleared to Mildenhall TACAN and to FL250, call leaving 290.

Elapsed
Time
Hr:Min

40

	(Response out of 290.) Roger Esso, London Military, call Eastern Radar 279.0 for further clearance.
	(Response) Roger Esso.
02:38	(Response to check in.) Eastern Radar ident. Esso, Eastern has radar contact. (Experimenter: Give the crew a break from comm tasks to study approach and brief.) Esso, this is Eastern. You are cleared to maintain FL250 to hold Northeast on the 073 radial 44 DME, right turns, 9 mile legs. Expected approach time for Lead aircraft is 1755 - say call sign of Lead aircraft.
02:44	

Elapsed
Time
hr. Min.

41

02:50

17:502

M.C.

Roger, time now is 1745.

Esso, Eastern has you entering
holding at Mildenhall. Call
Mildenhall 276.5 and monitor
this frequency.

(Metro response if required - 300
overcast. 1/2 mile, light drizzle
and fog.)

Esso 01, Eastern, you are cleared
for an immediate approach Hi
TACAN/ILS to Rwy 09. Contact me on
279.2 departing FL250.

(Response) Roger Esso, Dingbat,
say your maintenance status and
block time.

(Response) Roger, Esso, Dingbat
copies, weather is 300 overcast.
1/2 mile in light drizzle and fog.
Forecast to remain. Over.

02:52

Roger Eastern, Esso 01 is cleared
for an approach to 03, departing
FL250 and going 279.2 now. Break.
See you on the deck, 5.

Elapsed
Time
Hz: Mic

42

02:55

Esso 5, Eastern Radar you are cleared Hi TACAN/ILS runway 29. Call departing the initial approach fix.

(Response) Roger Esso 5 contact Honnington approach control 129.05.

(Response) Roger, Esso 5, Honnington. Squawk 2121 and ident. Radar contact. Esso 5 call intercepting localizer and final approach fix.

03:00

(Response) Roger Esso 5, by final approach fix, call tower 122.55.

(Response) Esso 5, Mildenhall Tower, you are cleared to land runway 29. Winds light and variable. QNH 2988 or 1012 Millibars. RCR wet runway. Call field in sight or

Elapsed
Time
hr:Min

43

initiating missed approach.

(Response) Roger Esso 5 recheck gear, cleared to land runway 29.

Esso 5, Mildenhall cleared left turn off at the end. Contact ground control 336.7 when clear.

03:05

1805Z

(Response) Roger, Esso 5, Ground, a follow me is on the way out. Your flight plan is closed.

MILDERHALL TO BODO B-52 REFUELING

Situation. The Klaxon has been sounded. Filip 61 and 66 are initiating a EW0 launch to support a flight of two B-52s, call signs Bozu 21 and 24 at 72° North. The crew of Filip 66 has completed EW0 preflight items and are ready to begin the Start Engine checklist and ready to copy launch message. The time is 2150Z. All nav aids are down. ATC comm is not required. Limited radio comm with formation and receiver is required for simulation.

Elapsed
Time
Hr:Min

00:00	This is Clock Control, Klaxon Klaxon. Klaxon standby for launch message.	(Ready to start engines.) For Filip flight, this is Clock Control. Takeoff on your scheduled timing. Time (<u>present</u> <u>Z time</u>)/(today's date). Authen- ticate Xray Yankee Zulu (wait for authenticate response). For Filip flight, message follows: Metro, Lima, Delta, (pause) Echo, Whiskey, Oscar, (pause) India, Foxtrot, Romeo, (pause) Sierra, Uniform, Papa, (pause) Echo,	(Ground crew responds:) Cartridges inserted. Chocks in place, engines clear, fire guard standing by. (Observe crew actions on TV monitor and call:) All 4 turning. (As throttles are advanced from off:) Good start on all 4 engines.

(Disconnect external power and
remove chocks.)

Elapsed
Time
hr:min

<p>00:03 Filip 61, Mildenhall Ground, Roger, winds 090 at 20. All aircraft on Mildenhall Ground Control frequency, clear taxi routes. There is a pri launch in progress. I rep t. All aircraft on Mildenhall Ground Control frequency, clear taxi routes. There is a priority launch in progress.</p>	<p>Uniform, Roro, (pause) Papa, Golf 355 (pause). Runway 11, wind 090/20, temperature 36, pressure altitude 35'. I say again, For Filip flight, message follows: (repeat message). Ground, Filip 61, we are taxiing.</p>	<p>(Ground crew responds:) Chocks, pitot covers, ground wires, and external power removed, upper and lower rotating beacons on and rotating, disconnecting interphone cord and coming (or not coming) aboard.</p>
		<p>66, 61 going Tower.</p>

Elapsed
Time
Hr:Min

00:04	Roger, Med Evac 471, Mildenhall Tower.	Mildenhall Tower, Med Evac 471. Roger, Tower, 471 is 7 miles on final for straight in landing, Runway 11. Tower, 471 requests Med Evac priority for landing.
00:05	Med Evac 471, Mildenhall Tower, negative. Hold south with Honington Control on 129.05 until further advised.	Tower, Filip 61 is rolling.
00:07 (2200Z) TAKEOFF	(Experimenter: Hack T/O time at 2200Z for crew.)	Filip 61 flight go A/R common and check in. (Filip 66) (Experimenter: Runaway elevator trim as soon as Filip 66 is airborne.)

Elapsed
Time
Hr:Min

5

00:30-00:35

Experimenter: Move flight forward to 59° North. The flight is level at FL350, on course to Sumburgh 009°, 270 knots indicated.
Fuel status 172K. Crew will have a few minutes to reorient to new position before continuing flight. Time will start at 2312Z.

00:36

Filip 66, this is 61. We've got stronger winds than we planned on. We're going to push it up to 450 knots true.
(Filip 66 copies. 450)

00:37

Filip 66, this is 61. Would you crosscheck my INS readings. At the present time my counters are reading N 591500 W 0012500.

00:42

(2319Z)

SUM

66, 61 by Sumburgh.
(66 copies)
(Experimenter: Crews should be getting at least two radar updates, one at SUM and one at SXV.)

Elapsed
Time
00:47

6

00:47

(23287)

SXV

66, 61 by Sixa Vord. Say your lat/long.
(66 copies)

00:48

66, 61 would you pass time and
dist from present position to ARCP
(approx. 700 miles/1+40).

00:52

Filip 66, this is 61. We are
losing power on #1. Our airspeed
is dropping off. Watch your
spacing.

(Experimenter: Lead closes gradually
toward 66 until 66 slows to 250 IAS.
Tracked by skin paint.)

00:55

66, this is 61. We've got an
engine fire in #1.

Elapsed
Time
hr:min

7

	<p>66, this is 61. We've got that fire and we can't get it out. We're going to descend and push the airspeed up and try to blow it out. We're going to have to abort here and head for landfill. Give me pigeons to the nearest landing strip.</p>
<p>00:56</p>	<p>(Response)</p> <p>Flip 61 copies. Thanks for the information.</p>
<p>00:57 (2334Z)</p>	<p>This is Sky Queen Control with a HF traffic message. Time (date/time). (in phonetics): Tango, Alpha, November, Kilo, Echo, Romeo, (pause) Romeo, Echo, Charlie, Alpha, Lima, Lima, (pause), Tango, Alpha, November, Kilo, Echo, Romeo, (pause) Romeo, Echo, Charlie, Alpha, Lima, Lima,</p>

(Experimenter: Skin paint should disappear.)

Elapsed

Time

Hr:Min

9

01:05	(Experimenter: Transmit weak and scratchy.)	Filip 61, Bozo 21. How do you read me on Uniform? (Go ahead Bozo 21, 66 here.) Filip 66, Bozo 21, have you weak but readable, weak but readable. Be advised I am trying to contact Filip 61 flight. (Response) Roger, Filip 66, Bozo 21. Request you authenticate Alpha Bravo, Alpha Bravo.
01:06	(Inside Experimenter: Hand the boom operator or copilot a cord with "Charley Delta" on it.)	Bozo 21, roger.
01:07		Filip 66, Bozo 21, be advised I am not painting your beacon. Filip 66, 21, I am ready to copy line up.

Elapsed
Time
Hr:Min

10

01:10

COMM INFO ONLY

Information to be confirmed:

Hot Armanent Check

Yes

ETA to Rendezvous
Point

Briefed

Rendezvous Altitude

Briefed

Inbound Track

Briefed

(Roger, sir. Filip 66 air refueling altitude will be as briefed, altimeter setting will be 2992, the offload will be modified due to Filip 61 abort, rendezvous heading will be 225, the drift inbound is four left. Weather in the air refueling is kind of rough, lot of towering cumulus, very rough ride. There is one tanker available.)

Filip 66, Bozo 21, we've got some weather showing up on the track. We would like to go to a new refueling track clear of the thunderstorms. Suggest new ARCP of 040° radial at 35 miles from old ARCP, how copy.

Elapsed
Time
Hr:Min

11

	<p>TAS for Rendezvous</p> <p>Turn Range & Offset</p> <p>(Roger, Roger, Filip 66, copy, and we agree to new refueling track.)</p>	<p>Briefed</p> <p>Briefed</p> <p>Roger, 66, 21, thank you.</p> <p>Filip 66 flight, Bozo 21. Come up on air to air TACAN.</p> <p>Filip 66, 21. Hold down for a DF steer.</p> <p>Filip 66, 21. My DF has you at one o'clock. TACAN shows 190 miles.</p> <p>66, 21, how much total fuel can you offload with minimum for recovery?</p> <p>(Experimenter: Approx. 130K)</p>
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01:12

01:15

Elapsed
Time
Hr:Min

12

		Bozo 21 copies 130K pounds total for both Bozo 21 and 24 - affirm?
		Roger 66. Plan 70K for Bozo 21 and the remainder for Bozo 24.
01:17		66, 21. My new ETA to ARCP is OLD ETA plus 5 min.
01:22	(Experimenter: Beacon should be at ARIP at 01:25.)	
01:25		21 copies 100 miles, passing ARIP. Filip 66, 21, be advised I still cannot paint your beacon. It looks like you may have to conduct the rendezvous. Try to paint my beacon now. Understand 66, you can paint my beacon.

Elapsed
Time
Hr.Min

13

01:26 (New ARCP)	21 copies 90 miles, at new ARCP, Are you on course toward ARIP?
01:27	21 copies 80 miles. Starting descent to 1500 feet below base.
01:28	21 copies 70 miles. 21 copies 60 miles.
01:29	21 copies 50 miles.
	66, Bozo 21 level 1500' low. Our inbound track is on flight plan. Our true airspeed is flight plan plus 4. 21 copies 40 miles.

Elapsed
Time
Hr:Min

14

01:30	Bozo 21 copies 30 miles. Copy 25. Copy 24. Copy 23. Copy 22.
01:31	21 copies. 66 in left turn at 21 miles. Call me half way through turn.
01:32	Bozo 21 copies. 12 miles. I think I have your lights in sight. It's pretty hazy.
01:35	66, Bozo 21. We've got you about 2 miles in front of us, skin paint and starting to get a good visual.
01:37 (0137Z) ARCT	Filip 66, Bozo 21, visual contact. You're in our 12 o'clock, about 3/4 of a mile we're climbing. Push it up (255 KIAS).

Elapsed
Time
Hr:Min

15

01:38	(Roger, Bozo 21. Filip 66, boom operator you're clear the radio. Bozo 21, Boom 66 how copy?)	Boom 66, read you 5. 66, Bozo 21. We'd like to get 70,000 pounds for receiver #1 and the remainder to go to receiver #2.
01:40	(Boom copies. Filip 66 is ready.) (21, you're clear to the pre-contact position.)	21 copies pre-contact.
01:49	(21, Boom 66, cleared to contact.) (Filip 66, contact.) (Bozo 21, Filip 66. You've got your offload - 70K.) (Bozo 21, disconnect now.)	Bozo 21 copies. Cleared to contact. Bozo 21, contact.
		Bozo 21, disconnect.

Elapsed
Time
Hr:Min

16

	(21, clear of boom.) (Bozo 24, Filip 66, boom operator you're clear to the pre-contact position.)	Bozo 24. Cleared to pre-contact.
01:51	(Bozo 24, Filip 66. Tanker is ready. Cleared to contact.) (Filip 66, contact.)	Bozo 24, coming in. Bozo 24, contact.
01:53	(Bozo 24, you are taking fuel.)	Bozo 24 copies taking fuel.
01:55 (0148Z)	(Inside Experimenter tells crew that there is a strong smell of something burning and can see a small amount of smoke.) (Bozo 24, disconnect now.) (24, Boom, standby, we have a problem here.)	24, disconnect. What's the problem, 66? 24 going to pre-contact.

Elapsed
Time
hr:Min

17

02:00	(Experimenter: Fuel should be down	(Bozo 24 cleared to contact. We	Bozo 24, coming in.
0153Z	to approx. 2000 pounds in each main tank, all other tanks dry, 8000 pounds on totalizer.)	are working the problem.)	
		(66, contact.)	Bozo 24, contact.
		(24, 66 has emergency squared away.)	24 copies, 66 back in the green.
		(Experimenter and boom, Bozo 24 has his onload 0158Z.)	
		(Bozo 24, you've got all the gas we can give you. Filip 66, dis- connect now.)	Bozo 24, disconnect.
02:05		(Bozo 24 clear of boom. Onload	Understand, 24 is clear of boom with
EAR		60K.)	60K onload.
0158Z			66, 21, say position down track from new ARCP.
		(Approx. 150 miles down track.)	Understand, present position is ARCP #2 plus 150NM, Charlie?

Elapsed
Time
Hr:Min

18

02:07	(HF message in code.) Sky Queen, Sky Queen for Filip 61, Bravo, Oscar, Delta, Oscar (pause). Romeo, Echo, Charlie, Oscar, Victor, Echo, Romeo, Yankee (pause). Charlie, Oscar, November, Foxtrot, India, Romeo, Metro, Echo, Delta (pause). Bravo, Oscar, Delta, Oscar (pause). Romeo, Echo, Charlie, Oscar, Victor, Echo, Romeo, Yankee (pause). Charlie, Oscar, November, Foxtrot, India, Romeo, Metro, Echo, Delta (pause).	66, 21 thanks for the juice.
	(Pause) Filip 66, Head Dancer on 87 upper. (Wait for response) Weak but readable. Go ahead with mission report.	(Experimenter: Crew should set up to go direct to Bodo at max range.)

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02:10-02:15

We now advance the flight to 69 North/1130 East along our route (150°-160°) to Bodo which puts us approximately 120 nautical miles northwest of Bodo, FL290, max range airspeed and about 3000 pounds of fuel remaining. When the flight resumes the time will be 0235Z. The crew should take a few minutes to reorient and start planning an airborne radar approach. Bodo Tower has not been contacted.

Elapsed
Time
Hr:Min

19

02:20

(Broken reply barely readable.)
Roger, Filip 66, Bodo Tower.
(Give following message unreadable
the first time - broken and un-
readable the second try.)

Filip 66, Bodo Tower present
weather is 400 and 1, 400 and 1.

Filip 66, how did you copy?

Go Victor, Go Victor (broken but
readable).

Filip 66, Bodo Tower. Altimeter
2000.

02:22

That was a roger on the weather.
Can you hold above flight level
2000 for minimum fuel fighters?
Roger.

(Experimenter: Bodo Tower UHF is
almost useless - VHF comm is OK.)

Scratch, scratch, scratch.

(When 66 switches to VHF comm,
repeat as necessary.)

AD-A100 851

DAYTON UNIV OHIO
KC-135 CREW SYSTEM CRITERIA.(U)
MAR 81 J H KEARNS, R MADERO, K BURNETTE

FLD 6

F33615-79-C-3030

UNCLASSIFIED

AFWAL-TR-81-3010

NL

3 OF 3

AD A
100851

END

DATE

FILED

7-81

DTIC

Elapsed
Time
Hr:Min

20

<p>02:24</p> <p>Filip 66, Bodo Tower be advised my nav aids are down. You're clear to approach with onboard system.</p> <p>Call departing Flight Level 100. Call 10 mile final. Please expedite.</p>	
<p>02:28</p> <p>Roger, Filip 66. I have you out of Flight Level 100. Call 10 miles final.</p> <p>Roger, 66, Bodo, 10 out. Call field in sight. Be advised I have minimum fuel fighters close behind. about 10 miles. Be prepared to land long or clear active immediately, over.</p>	
<p>02:33</p>	<p>(Experimenter: #1 and #2 engines fail with attendant yaw and failure lights. Fuel quantity in main tanks shows fuel exhaustion in tanks 1 and 2 and a couple hundred pounds in 3 and</p>

Elapsed
Time
Hr:Min

21

4. Totalizer shows 400 pounds.)

02:34 Roger, 66, Bodo copies engine
flame out. Crash has been
alerted. Can you make the field?

02:35 Bodo copies 66. I have you in
0255Z sight, cleared for arrival.

Fin EWO

BODO TO AALBORG

Situation. Filip 66 has been directed to proceed from Bodo, Norway to an anchor point to refuel random flights of fighters with an Aalborg, Denmark recovery. Takeoff is scheduled for 0700Z, ARCT is 0830Z. (Start engines 0645Z-Hack time) Taco 33 will be number 2 tanker. GCI, call sign Blackball, will direct the receivers to the fighters on 364.2. A/R frequency is 326.6 Bodo Tower, 118.1 or 270.1. Filip 66 flight has completed the Preflight and Interior Inspection checklists and are ready to start engines. This is a contingency mission, not an EW0. There is no SAC Command Post at Bodo.

Elapsed

Time

Hr:Min

00:00	(Give launch message on HF.) For Filip 66 flight, this is Temper Control. Takeoff on your scheduled timing. Time (present Z time)/(today's date). Authenticate Golf Alpha Sierra (wait for authenticate response). For Filip 66 flight, message follows: Bravo, Delta, Oscar, (pause) Alpha, Alpha, Lima, (pause) India, Foxtrot, Romeo, (pause) Sierra, Uniform, Papa, (pause) Echo, Uniform, Romeo, (pause) Papa, Golf, Three, Five, Six, (pause). Runway information unknown.
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Elapsed
Time
Hr:Min

2

<p>I say again, For Filip 66 flight, message follows: (repeat message).</p>	<p>Filip 66, Taco 33 ready to crank engines.</p> <p>(Ground crew replies:) Chocks in place, engines clear, fire guard standing by. (Ground crew reports by observing crew action in TV monitor:) #1 turning. Good start on #1.</p> <p>(#1 switch activated.) (#1 throttle to idle.) (REPEAT FOR ENGINES 2, 3, and 4.) (Disconnect external power and remove chocks.)</p> <p>(Ground crew replies:) Chocks, pitot covers, ground wires, and external power removed; upper and lower rotating beacons on and rotating; disconnecting interphone cord and coming (or not coming) aboard.</p>
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Elapsed
Time
Hr:Min

3

00:04	Filip flight, Bodo Ground, call when ready to taxi. (Response)	Filip 66, Taco 33 is ready to taxi.
00:06	Filip flight, this is Bodo Ground, clear to taxi runway 26. Altimeter 2988. Pressure Altitude 45 feet. Temperature 3 degrees centigrade. (Response) Filip flight, Bodo Ground. You are cleared as requested, Flight Level 300. Change now to tower frequency (270.1). (Experimenter: Move forward to 0658 if crew is ready for Take Off.)	Taco 33, copy. Taco 33 copies.
00:09	(Response) Roger, Filip flight, this is Bodo Tower, you're cleared for takeoff.	66, Taco 33 ready for takeoff.

Elapsed
Time
Hr:Min

4

	Runway 26, winds are 270 at 10. Departure Control 119.7. Squawk 2032.	
00:10	Filip 66, Tower, cleared left turn on course, cleared to contact Blackball Control on 364.2.	Taco 33 copies. (66 rolling)
00:12		Taco 33 rolling.
00:14	(Response) Filip 66, Blackball Control, I read you 5 by. My weapon is saturated. Proceed to anchor via flight plan route. Call Blackball crossing anchor.	Taco 33 is airborne on tanker frequency.

00:15

66, 33 be advised my nav management system is shot. Give me a call passing waypoints.

Filip 66, 33 here. I'll be in position in a few minutes. Can you pull it back a little?

Thanks, 33.

00:17

66, 33 in position - push it up.

[illegible]

00:17-00:25

The flight moves forward to 3 minutes prior Soderhamm (NBD Skallen) at FL300, 500 TAS, 150° on course, weather is WMC, fuel status 138K. There is no air traffic control. Blackball is still saturated. When we resume flight the time will be 0800Z. The crew may take a few minutes to reorient and update prior to resuming flight.

Elapsed
Time
Hr:Min

6

00:25	66, 33 here, would you give me the numbers (course, distance and time) to wpt #2. I think my system is coming back on line. (Response) Roger 66. Call me passing wpt #2.
00:28	33 copies by waypoint #2, going 166°. Say pigeons to wpt #3. (Time and Dist)
00:32	(Experimenter: Crew should perform one or two radar updates (at Hammar, etc.).
00:38	66, 33 here, I would like to run a check on my computer. Would you give me the numbers, present position direct to the ARCP? (Response) Thanks 66. (Experimenter: Pre-contact checklist should be completed.)

Elapsed
Time
Hr:Min

7

00:43	33 copies by waypoint #3, going 137°.	
0818Z		
Stockholm		
00:50	66, 33 here, my nav management system has gone out again.	
00:55	33 copies ARCP (185° for teardrop)	
0830Z	or (turning 216 for outbound leg).	
ARCP		
	Filip 66, Blackball, say your position.	
	Roger 66 - Squawk ident.	
	66, Blackball radar contact, standby.	
	Roger, Filip 66, Blackball, I have you at anchor.	
00:57	Filip 66, Blackball, standby for Vixon, flight of 6 A-7s.	
	Vixon flight, this is Blackball Control, over.	Vixon reads you loud and clear, Blackball.
	Roger Vixon, maintain Flight Level 270 until visual on tanker.	Vixon copies - level Flight Level 270.

Elapsed
Time
Hr:Min

8

<p>Filip flight, Filip flight, this is Blackball Control.</p>	(Filip 66)	
<p>00:58 Roger, Filip 66, Blackball Control. Make a left 180 for inbound (or outbound) anchor.</p>		
<p>Vixon flight, this is Blackball Control. Roger, Vixon, when the tanker rolls out of his turn he will be at your 10 o'clock position four miles going away.</p>		<p>Blackball, Vixon here, go ahead.</p>
<p>01:00 Roger, Vixon, Blackball, clear my frequency.</p>		<p>Blackball, Vixon. I have tally ho on the tanker.</p>
		<p>Vixon flight go refueling common. (326.6) Vixon Lead. 2, 3, 4, 5, 6. Filip 66, this is Vixon.</p>

Elapsed
Time
Hr:Min

9

01:02	<p>(INFO ONLY for Comm)</p> <p>(Do not transmit. Filip 66 may transmit a similar lineup):</p> <p>Altimeter Setting 2992</p> <p>Offload As Required</p> <p>Refueling Heading 039/222</p> <p>Drift Inbound Drift 3 left</p> <p>Weather in A/R Area Some Buildups</p> <p>Number of Tankers Available 2</p> <p>Other Info to be Confirmed:</p> <p>Hot Armament Check</p> <p>Inbound Track 036</p> <p>TAS for Rendezvous As requested</p>	<p>33 on frequency.</p> <p>33 copies, 280 indicated.</p>	<p>(Response)</p> <p>Vixon flight has a tally ho and climbing.</p> <p>We'll be sliding into the pre-contact position. Can you give Vixon 280 indicated?</p> <p>66, Vixon, how do we line up?</p> <p>3 left and three right?</p> <p>(Response)</p> <p>Roger, 66, you want 3 Vixons on tanker 1 and 3 Vixons on tanker 2.</p> <p>Be advised we need about 4 thousand each for top off.</p> <p>(Response)</p> <p>Vixon flight, Roger, 4, 5, and 6 take #2 tank. 1, 2, and 3 will take the lead tank.</p>
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Elapsed
Time
Hr:Min

10

01:05 Filip flight, this is Blackball
Control.
Roger, Filip. Be advised I am
starting to paint significant
weather on your anchor track.
Do you paint?
Roger, 66, you're cleared to deviate
for weather. Keep me advised.

01:06 Filip 66, Blackball Control. Be
advised we have a second flight
of chicks inbound to your anchor
track at this time. Will advise
when they're within 50 miles.

33 copies weather.

01:07

(Vixon Lead, boom 66, how copy?)
Vixon 4, boom 33, how copy?
(Lead clear to contact.)

66, Vixon Lead copies 5.
33, Vixon 4 copies 5.
Vixon Lead copies.

Elapsed
Time
Hr:Min

1:

01:08	Filip 66, Blackball, ident. (Pause) Roger 66, say your position from anchor fix. (Response) Roger 66, Blackball, I have you now.	4, clear to contact. (Boom 66, contact.) Boom 33, contact.	Vixon 4 copies. Vixon Lead, contact. Vixon 4, contact.
01:10	66, Blackball, standby to turn left. (<u>Experimenter computer deck</u> gives weather cells inside track on HSD weather display if selected.)	(Vixon Lead disconnect now.) (Vixon Lead clear of boom 3800 pounds.)	Vixon Lead, disconnect. Vixon Lead copies 3800.
01:11	66, Blackball, turn left to inter- cept inbound (or outbound) track.	Vixon 4, disconnect now. 33 copies turn. Vixon 4, clear of boom with 4000 pounds. (Vixon 2, clear to contact.) Vixon 5, clear to contact.	Vixon 4, disconnect. Vixon 4 copies 4000. Vixon 2 copies. Vixon 5 copies.
01:12		(Boom 66, contact.)	Vixon 2, contact.

Elapsed
Time
Hr:Min

12

01:14		(Vixon 2, disconnect now.) Vixon 5, disconnect now.	Vixon 2, disconnect. Vixon 5, disconnect.
01:15	(Experimenter: New weather cell, 12 o'clock, 12 miles.)	(Vixon 2, clear of boom 4200 pounds.) Vixon 5, clear of boom with 4300. (Vixon 3, clear to contact.) Vixon 6, clear to contact.	Vixon 2 copies 4200. Vixon 5 copies 4300. Vixon 3 copies. Vixon 6 copies.
01:16	Venom flight, this is Blackball Control, over.	(Boom 66 contact.) Boom 33, contact.	Blackball, Venom here, read you 5. Vixon 3, contact. Vixon 6, contact.
01:17	Roger Venom, your tank is in the block. Head 060 approximately 80 miles. Maintain Flight Level 270.		Venom, Roger, 060 and Flight Level 270.

Elapsed
Time
Hr:Min

13

01:18		(Vixon 3, disconnect now.) Vixon 6, disconnect now.	Vixon 3, disconnect. Vixon 6, disconnect.
01:19	(Experimenter: Clear of weather cell.)	(Vixon 3, clear of boom 4500 pounds.) Vixon 6, clear of boom with 4400 pounds.	Vixon 3 copies 4500 pounds. Vixon 5 copies 4400 pounds.
01:20	Filip 66, Blackball, turn inbound to (or outbound from) anchor. I have more customers in line, a Venom flight of 4 F-16s.	33 copies turn.	Vixon flight, reform on lead Break. Filip, thanks for gas. Vixon is clear of cell. Vixon go button 12.
01:21			Venon Lead, Venom 4 has Bingo minus 1000 pounds. Lead copies 4. Lead, Venom 5 has Bingo minus 1200 pounds. Lead copies 5.

Elapsed
Time
Hr:Min

14

01:22	<p>Filip, Blackball, Venom flight is inbound to your position approx. 50 miles. (Or standby for vectors)</p> <p>(Experimenter: Give vectors to Filip as required.)</p> <p>01:25 Venom flight, this is Blackball Control.</p> <p>Roger, Venom. Blackball, your tanker is 11 o'clock, 25 miles and they will be making a left turn.</p>	<p>Filip 66, Venom. (Response) Roger, Filip 66. Venom here, I have two aircraft down to emergency fuel. Can you come to meet us.</p> <p>33 copies Blackball.</p> <p>Go ahead, Blackball, Venom here.</p> <p>Venom, Roger.</p>
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Elapsed
Time
Hr:Min

15

<p>01:26</p>	<p>Filip flight, this is Blackball Control. Roger, sir, your chicks are at 20 miles inbound. Make a left 180 for inbound to mission fix (or outbound). 33 copies left turn.</p>	<p>Filip flight, Venom, would you pass some gas to help me locate you. We are really hurting for fuel and need all the help we can get.</p>
<p>01:27</p>	<p>Venom flight, this is Blackball Control. Roger, Venom, your tankers are 12 o'clock, 10 miles. (Experimenter: Crew should set up for fuel dump: boom retract; A/R pump on; dump switch on.)</p>	<p>Go ahead, Blackball, Venom here. Venom, Roger, I have a tally ho and climbing to your altitude. 66, do you pass gas on this frequency or standard A/R frequency? (Response)</p>

Elapsed
Time
Hr:Min

16

<p>01:28 Vampire 3, this is Blackball Control.</p> <p>Roger Vampire, Blackball, I have a tanker that will be available soon.</p>	<p>Roger Blackball, Vampire 3 hears you loud and clear.</p> <p>Roger Blackball, Vampire is ready for vectors to tanker.</p>	<p>Venom flight, let's go to refueling frequency and check in. Venom flight, check in. 3, 4, 5.</p> <p>Filip 66, Venom.</p>
		<p>(Respond) Roger, 66, I'll take 300 indicated and 8000 per bird if you can spare it. Filip, Venom, do you want us to split, 2 on lead and 2 on #2 tank?</p> <p>Venom Lead, Roger.</p> <p>4 go to the lead tank, 5 take the second tank. Lead on lead, 3 on 2. 3 copies.</p>

Elapsed
Time
Hr:Min

17

01:29	Roger, Vampire turn to a heading of 010; approximately 100 miles to anchor.	Roger, Blackball, Vampire 3.	4 copies. 5 copies. Filip 66, this is Venom Lead. 2 got split up from Venom flight. He'll be arriving in about 5 minutes and he may be hurting for fuel also.
01:30	Filip flight, this is Blackball Control. (Response) Roger Filip, I have a single ship inbound to you at this time. Call sign Vampire 3. He's an RF-4.	(Venom 4, Boom 66, how copy?) Venom 5, Boom 33 how copy? (Venom 4, clear to contact.) Venom 5, clear to contact.	Venom is in pre-contact, ready for gas. 66, Venom 4 reads you 5. 33, Venom 5 reads you 5. Venom 4 copies. Venom 5 copies.
01:31	Roger 66, Blackball, single chick is about 80 miles out.		

Elapsed
Time
Hr:Min

18

01:32	(Experimenter: Message on HF radio: For Filip 66 flight Alpha, Alpha, Lima, Bravo, Oscar, Romeo, Golf, (pause), Romeo, Echo, Charlie, Oscar, Victor, Echo, Romeo, Yankee, (pause), Charlie, Oscar, November, Foxtrot, India, Romeo, Mike, Echo, Delta.)	(Boom 66, contact.) Boom 33, contact. (Venom 4, disconnect now.)	Venom 4, contact. Venom 5, contact. Venom 4, disconnect.
01:34	Vampire 3, this is Blackball. Roger, sir we show you right now at 30 miles. Maintain heading of 020, over.	Venom 5, disconnect now.	Roger Blackball, Vampire 3, go. Vampire 3, Roger 020. Venom 5, disconnect.

Elapsed
Time
Hr:Min

18a

01:35	Filip flight, this is Blackball Control. Roger, sir. You have single chick inbound at 30 miles. We'll keep you advised, 66.	(Venom 4, clear of boom 9300#) Venom 5, clear of boom with 9500. (Filip 66, go ahead.) (Roger, Blackball, Filip 66.)	Venom 4 copies 9300 pounds. Venom 5 copies 9500 pounds.
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Elapsed
Time
Hr:Min

19

01:36		(Venom Lead clear to contact.) Venom 3, clear to contact.	Venom Lead copies. Venom 3 copies.
01:37	Filip 66, be advised the weather situation seems to be deteriorating. Use your own discretion as far as navigation within the track.	(Boom 66, contact.) Boom 33, contact. 33 copies. (Filip 66, Roger.)	Venom Lead, contact. Venom 3, contact.
01:39		(Venom Lead, disconnect now.) Venom 3, disconnect now.	Venom Lead, disconnect. Venom 3, disconnect.
01:40	Vampire 3, this is Blackball Control. Roger, your tanker is in the nine o'clock position approximately 4 miles, advise when tally ho.	(Venom Lead, clear of boom 9500#) Venom 3, clear of boom 9700#.	Venom Lead copies with 9500#. Venom 3 copies 9700#. Blackball, Vampire 3, go ahead.
			Vampire 3, tally ho. Standing by

Elapsed
Time
Hr:Min

20

<p>Roger, Blackball copies.</p>		<p>for other chicks to clear your boom. Roger, Filip 66, Vampire 3 here, going A/R frequency 326.6.</p>
<p>01:41</p>	<p>(Roger, Vampire, go ahead.)</p>	<p>Venom flight, reform on lead. Roger, Vampire 3 on A/R frequency. Your boom is clear, I'm climbing. Can you hold 305 indicated and give me ten thousand pounds?</p>
	<p>(Vampire 3, Boom 66, how copy?)</p>	<p>Blackball Control, this is Vixon 7. (Response) Boom 66, Vampire 3 reads you 5 by.</p>
<p>Roger, Vixon 7, this is Blackball Control, over.</p>		<p>Roger, Blackball. Vixon here. I'm in an emergency fuel situation and I won't be able to make it to the anchor. I request a tanker divert.</p>

Elapsed
Time
Hr:Min

21

01:42	Roger, Vixon 7. Assume a heading of 360 at this time and I will be in contact with the tanker.	Roger, Vampire 3, clear to contact.	Filip 66, Venom, thanks for the gas. We're up and away. Venom flight, let's go button 12. Vampire copies, clear to contact.
01:43	Filip flight, this is Blackball Control.	(Boom 66, contact.) (Roger, Blackball, Filip.)	Vixon 7, Roger. Vampire 3, contact.
01:44	Roger, Filip. We have an emergency situation with Vixon 7 a single A-7. Can you turn to a heading of 165° for intercept and refueling? Request you leave Taco 33 in anchor for another min fuel inbound.		Boom 66, Vampire 3 here, I'm going to disconnect now. I was taking a lot of spray. I'll try again.

Elapsed
Time
Hr:Min

22

01:45	<p>Roger, Filip 66, I will provide radar intercept.</p> <p>Taco 33, Blackball, come up 364.4 and check in.</p> <p>Filip 66, this is Blackball Control. I have Vixon 7 on radar approximately 120 miles on your reciprocal.</p> <p>Roger, Venom 2, Blackball Control.</p>	<p>(Filip 66, turning South at this time.)</p> <p>Taco 33 copies. Break. 66, Taco 33 here, call me when you return to anchor.</p> <p>33 copies. I'll stay here in the anchor.</p> <p>(66)</p> <p>(Vampire 3, cleared to contact.)</p>	<p>Vampire 3 at pre-contact.</p> <p>Blackball, this is Venom 2.</p> <p>Roger Boom, Vampire 3 cleared to contact.</p> <p>Roger, Blackball, Venom 2 is inbound to the tanker orbit, emergency fuel, request immediate refueling.</p>
01:47	Venom 2, Blackball, ident.		

Elapsed
Time
Hr:Min

23

<p>Roger, Venom 2, be advised we do have a tanker inbound to your location. Standby Venom.</p> <p>Venom 2, this is Blackball Control.</p> <p>Roger, sir. We have another emergency fuel situation. Filip 66 is inbound to Vixon 7. He is 100 miles north of your location, Venom 2. We'll go ahead and try to effect your rendezvous with both chicks, over.</p> <p>01:48 Filip 66, this is Blackball Control.</p> <p>Roger, sir. We have another emergency with Venom 2. He is approximately 100 miles out. We will try to effect a rendezvous with this aircraft as well as Vixon 7, who is at 50 miles.</p>	<p>(Boom 66, contact.)</p> <p>Vampire 3, contact.</p> <p>That's better 66, Vampire 3 is OK now, taking fuel.</p> <p>Go ahead, Blackball, Venom 2 here.</p> <p>Venom 2, Roger.</p> <p>Vampire 3, disconnect. Sorry Boom, this bird is a real dog. Back to pre-contact.</p>
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Elapsed
Time
Hr:Min

24

01:50	<p>Venom 2 this is Blackball Control.</p> <p>Roger, sir, assume a heading of 350 and have the tanker at approximately 100 miles.</p>	<p>Roger, copy.</p> <p>(Vampire 3, cleared to contact.)</p>	<p>Go ahead, Blackball, Venom 2.</p> <p>Roger Boom, Vampire 3 cleared to contact.</p> <p>Venom 2, Roger.</p>
01:51	<p>Vixon 7, this is Blackball Control.</p> <p>Roger, sir, I'd like you to initiate a left turn 180° to affect a rendezvous with Filip 66.</p> <p>Maintain Flight Level 280 until visual.</p> <p>Filip 66, Blackball Control.</p> <p>Roger, sir, I have your receiver 12 o'clock, 10 miles and 2000' low. He is making a left 180 in order to fall in behind.</p>	<p>(Boom 66, contact.)</p> <p>(Filip 66, go ahead.)</p> <p>(Filip 66 copy.)</p>	<p>Blackball, go ahead, Vixon 7 here.</p> <p>Vampire 3, contact.</p> <p>Vixon 7, Roger, FL280, head 180.</p>
01:52			<p>Vixon 7 tally ho on tanker and climbing</p> <p>I'm about to flame out, 66.</p> <p>Can you clear your boom?</p>

Elapsed
Time
Hr:Min

25

01:53	<p>Filip 66, this is Blackball Control.</p> <p>Roger, sir, we have unidentified aircraft on our scope at this time, approximately 190 miles east of your position.</p>	<p>(Vampire 3 disconnect now.)</p> <p>(Vixon 7, Boom 66, how copy?)</p> <p>(Vixon 7, cleared to contact.)</p> <p>(Roger, sir. I understand bandits 190 miles in the East.)</p> <p>33 copies bandits.</p>	<p>Vampire 3 disconnect.</p> <p>Vampire 3 is clear of boom. I'll fly your wing, 66.</p> <p>Roger, Boom 66, Vixon 7 reads you 5 by at pre-contact. I need twelve thousand pounds fuel.</p> <p>Vixon 7, copies cleared to contact.</p>
01:54	<p>Venom 2, this is Blackball Control.</p> <p>Roger, Venom 2. You're approx. 25 miles from the tanker at this time.</p> <p>I'm going to be initiating a right turn for the tanker and his chicks and affect a rendezvous for you.</p>	<p>(Boom 66, contact.)</p>	<p>Go ahead, Blackball, Venom 2.</p> <p>Vixon 7, contact.</p> <p>Venom 2, Roger.</p> <p>I appreciate it.</p>

Elapsed
Time
Hr:Min

26

<p>Filip 66, this is Blackball Control, start a 180° turn to the right at this time. Venom 2 is 12 o'clock 20 miles. Be advised you are pressing the border.</p>	<p>(Filip 66)</p>	<p>Roger 66, Vixon 7 copies 180° turn to the right.</p>
<p>01:56 Venom 2, this is Blackball. Your tanker is 12 o'clock position, 4 miles with the chick.</p>		<p>Venom 2 has a tally ho.</p>
<p>01:57 Filip 66, this is Blackball Control. Roger, sir. We have bandits 50 miles from the East.</p>	<p>(66) (Vixon 7 disconnect now.) (Vixon 7, clear of boom with 12.6K fuel.)</p>	<p>Vixon 7, disconnect. Vixon 7 copies 12.6 fuel. Clear of boom. Thanks 66. Vixon 7 is clear of cell, leaving your frequency.</p>
<p>Filip 66, Blackball Control.</p>	<p>(Roger, sir.)</p>	<p>Filip 66, Vampire 3, I think I'll depart your cell now.</p>

Blackball, Vixon 7 back on your frequency.
Say again position of bandits.
Vixon 7 copies.

Venom 2 has been hit.

EMP

(Experimenter: Turn off power to all instruments except altitude, airspeed, V/V and standby compass. Also, turn of all comm.)

(Experimenter: Boom operator is flash blinded. Crew should attempt a DR to Aalborg.)

APPENDIX D

WORKLOAD RATING SHEET
FOR USE BY EXPERIMENTERS

SORTIE: _____

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APPENDIX E

PERFORMANCE ASSESSMENT QUESTIONNAIRE

APPENDIX E
PERFORMANCE ASSESSMENT

Crew Position: _____

AREA BEING ASSESSED: (check one block only, use separate sheet
for each block, a total of 8 sheets)

- ☐ Workload
- ☐ Emergency
- ☐ Crew Accommodations
- ☐ Mission Effectiveness
 - ☐ Take off
 - ☐ Enroute
 - ☐ Refueling
 - ☐ Cargo Delivery
 - ☐ Landing

Check the box which best reflects your opinion.

- ☐ 1. Not acceptable. Unsafe to use. I won't fly this cockpit.
- ☐ 2. Not acceptable. Cannot perform the mission. I won't fly this cockpit.
- ☐ 3. Marginal. Performance entails great difficulty or risk. Probability of successful mission is under 10%. I don't want to fly this cockpit.
- ☐ 4. Marginal. Performance is very demanding. Probability of successful mission is under 50%. I don't like flying this cockpit.
- ☐ 5. Marginal. Performance is demanding. Probability of successful mission is under 70%. I don't like flying this cockpit.

- ☐ 6. Conditionally acceptable. Requires modification. I can fly this cockpit.
- ☐ 7. Conditionally acceptable. Requires changes and/or adjustment. I don't mind flying this cockpit.
- ☐ 8. Acceptable. Requires minor changes. I like flying in this cockpit.
- ☐ 9. Acceptable. Requires minor adjustment. I like flying in this cockpit.
- ☐ 10. Completely acceptable. I like flying in this cockpit.

NAME _____

COMMENTS: (Please expand upon your reasons for the rating which you gave.)

APPENDIX F

QUESTIONNAIRE FOR PHYSICAL ASSESSMENT

APPENDIX F

PHYSICAL ASSESSMENT

AREA BEING ASSESSED: (check one block only, use separate form for each block which you assess)

- | | | |
|--|--|---|
| <input type="checkbox"/> LOGISTICS | <input type="checkbox"/> TRAINING | <input type="checkbox"/> FLIGHT CONTROL |
| <input type="checkbox"/> MAINTENANCE | <input type="checkbox"/> LIFE SUPPORT | <input type="checkbox"/> POWER PLANT |
| <input type="checkbox"/> RELIABILITY | <input type="checkbox"/> LIGHTING | <input type="checkbox"/> COCKPIT GEOMETRY |
| <input type="checkbox"/> SURVIVABILITY | <input type="checkbox"/> HUMAN FACTORS | <input type="checkbox"/> EXIT/ENTRY, ESCAPE |
| | <input type="checkbox"/> AVIONICS | <input type="checkbox"/> INSTRUMENTS AND CONTROLS |

Check the box which best reflects your opinion.

- ☐ 1. Not acceptable. Unsafe, impractical, failure prone, enormously expensive.
- ☐ 2. Not acceptable. Potentially correctable with major redesign.
- ☐ 3. Marginal. Discrepancies which can seriously lower the probability of mission success or survival.
- ☐ 4. Marginal. Discrepancies which are serious and can lower the probability of mission success or survival.
- ☐ 5. Marginal. Discrepancies which have significant impact and which reduce the probability of mission success.
- ☐ 6. Conditionally acceptable. Discrepancies which have a significant impact and which must be corrected. Not cost effective.
- ☐ 7. Conditionally acceptable. Discrepancies which have a small but significant impact and which should be corrected.
- ☐ 8. Acceptable. Minor discrepancies which should be adjusted.

- ☐ 9. Acceptable. Very minor discrepancies which do not have significant impact.
- ☐ 10. Completely acceptable.

NAME _____

COMMENTS: (Please expand upon your reasons for the rating you selected.)

END

DATE
FILMED

7-18-11

DTIC